INTERACTIONS BETWEEN WILDLIFE AND SALMON FARMS IN BRITISH COLUMBIA: RESULTS OF A SURVEY

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INTERACTIONS BETWEEN WILDLIFE AND SALMON FARMS IN BRITISH COLUMBIA: RESULTS OF A SURVEY

Harriet Rueggeberg and Jacqueline Booth
Hammond Bay Environmental Services

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PREFACE

This report is one component of a project sponsored by the federal Departments of Environment and Supply and Services that is aimed at assessing the effects of British Columbia's growing aquaculture industry on its marine bird populations. The project is comprised of three phases. Phase I reviewed the relevant literature, describing the nature of interactions that can occur between marine birds and the various types of aquaculture, and providing an analytical framework for the subsequent phases (Booth and Rueggeberg, 1988). In Phase II, a computer database and geographical information system is being developed to examine the overlap between areas of current and potential aquaculture development and areas that provide prime marine bird habitat (Booth and Rueggeberg, in preparation). Phase III consists of two studies that examine on-site interactions between birds and aquaculture, one dealing with salmon farming and the other with mussel farming.

This report documents the results of the Phase III study covering interactions between birds and salmon farms. In response to a request from the Wildlife Branch of the B.C. Ministry of Environment, the study was extended to deal not only with birds but also selected marine mammals and furbearers.

SUMMARY

This report documents the results of a study of interactions between wildlife and salmon farms in British Columbia. The objective was to determine appropriate planning, management and husbandry measures to avoid detrimental impacts of wildlife on salmon farms and of salmon farms on wildlife.

Information on current problems encountered with wildlife and the methods used to deal with these problems was collected by conducting a survey of B.C. salmon farms in June-August 1988. A questionnaire was sent to 87 salmon farming companies that requested information on:

- the occurrence of wildlife around their farms and any changes in the frequency of these occurrences as the farms became established.
- the nature of interactions and problems with individual species.
- the measures used to counteract problems, their costs and effectiveness.
- farm or site characteristics that may be factors in creating or amplifying these problems.

Seventy questionnaires covering 73 farm sites were returned by mail or filled out in site visits or by telephone. This represents a response rate of 62% of the companies, which in turn represents approximately 60% of the salmon farms in operation at the time of the survey.

The responses indicated that the 14 wildlife species/groups covered in the questionnaire occur around the majority of the farm sites. Relatively few respondents, however, indicated whether the frequencies of occurrence had increased or decreased since farms had been established; hence, it was not possible to detect whether the farms were displacing wildlife from these areas.

Only a proportion of farms that reported the presence of a wildlife species or group experienced problems with that species/ group. River otter, seals, mink, sea lions and Great Blue Herons were cited most frequently; over 50% of respondents reported problems with each of these species.

Predation was the most commonly cited problem in the survey, especially by river otter and seals. However, the number of farms reporting actual losses of fish was less than the number that stated that they experienced predation problems, suggesting that some operators considered predators a problem on the basis of potential rather than actual predation or on the basis of stress caused by the presence of these predators. On the other hand, the percentages of farms that lost fish to various predators were the same as or greater than those who rated predation as a severe

problem, suggesting that some operators view predation as a minor problem even though they experience some losses.

Total losses to predation by all wildlife for the year prior to the survey were in the order of 105,000 fish, with seals and otter accounting for 58,000 and 30,600 respectively. In addition, some 44,000 fish were lost through holes in netpens created by seals, sea lions or river otter. Extrapolating these results to the rest of the salmon farming industry, total wildlife-related losses over the last year could be 147,000 to predation and 61,600 to escapement. These figures represent about 1.5% of the 14 million fish stocked in 1987. In addition, 8 farms reported equipment damage caused by wildlife (primarily otter and mink) collectively costing $21,785.00.

Entanglement of mammals was an uncommon occurrence on the farms surveyed. Most entanglement involved birds, particularly Great Blue Herons, Belted Kingfishers and diving ducks. Mortalities due to entanglement could not be estimated from the survey data, but based on discussions with operators, mortality rates were low.

A number of farm characteristics were considered as potential factors in problems with wildlife, including farm size, age and netpen structure, the size and species of salmon raised, proximity to colonies or concentrations of wildlife, site management practices, and the size and colour of mesh used in predator nets. On the basis of these factors, the empirical results of the survey and discussions with farm operators, a number of recommendations for reducing negative interactions with wildlife are made.

* The location of seal and sea lion rookeries, haulouts and wintering sites and marine bird colonies or concentrations should be taken into account in the planning and approval of farm sites.

* Anti-predation methods should be considered first as preventive measures and only secondarily as cures to problems once they have already arisen. Exclusion measures such as predator nets, top nets and electric fences should be installed from the start of farming operations, preventing potential predators from developing predatory behaviour patterns around the farm.

* Predator prevention methods require regular monitoring, maintenance and a commitment of time and money resources to keep them in good operating condition.

* Good husbandry techniques taken in the interests of the health of farm fish are also good predator prevention measures. Storing feed in sealed bins or in sheds and frequent removal of dead fish from netpens will reduce the attractiveness of a site to predators.

* Bag nets and double bottomed nets provide the most effective protection against seals and seal lions. Seal bombs and shooting appear to be effective if used before the animals have developed a permanent interest in the site. Underwater acoustics may initially be effective, but there is evidence that their effectiveness diminishes after 2-3 years of use.

* Top nets or a combination of top nets and jump nets are effective deterrents to river otter and mink. Electric fences are also very useful if properly installed and maintained.

* Top nets or similar overhead structures are the most important method for preventing predation by aerial birds. They should be made of 3" mesh or smaller and should be kept taut and well above the water surface (>1 m). Brightly coloured top nets are more visible to birds and reduce entanglement problems. Overhead wires, twine or ropes with a spacing of about 0.5-1 m are probably sufficient to protect penned fish from eagles, osprey or other birds of prey.

* Underwater predator nets are the most effective means of preventing predation or slashing of penned stock by diving birds. A mesh size of less than 4" is recommended to avoid entanglement.

RÉSUMÉ

Vous trouverez dans le rapport les conclusions d'un sondage sur l'interaction entre la faune et les piscifactures de saumon en Columbie-Britannique. Cette étude a été menée dans le but de déterminer les mesures de planification, de gestion et d'élevage permettant d'éviter que la faune ne nuise aux piscifactures de saumon et vice versa.

Les données sur les problèmes occasionnés par la faune et sur les méthodes employées pour les pallier ont été recueillies du mois de juin au mois d'août 1988 dans la cadre d'un sondage mené auprès des pisciculteurs de la Colombie-Britannique. Quatre-vingt-sept piscifactures de saumon ont été priées de répondre à un questionnaire qui portait notamment sur les points suivants:

- la présence de la faune à proximité des piscifactures et tout changement noté à cet égard lors de l'établissement des piscifactures.
- la nature des rapports entre la faune et les piscifactures et les problèmes causés par les différentes espèces.
- les mesures adoptées pour contrer les problèmes, leur coût et leur efficacité.
- les particularités des piscifactures ou de leur emplacement qui peuvent avoir créé les problèmes ou les avoir exacerbés.

Soixante-dix questionnaires, portant sur un total de 73 piscifactures, ont été retournés par la poste ou ont été remplis au téléphone ou à l'occasion de visites de piscifactures. Soixante-deux pour cent des entreprises, ce qui équivaut à 60 pour cent de l'ensemble des piscifactures en exploitation au moment du sondage, ont répondu au questionnaire.

L'analyse des réponses recueillies révèle la présence de 14 espèces animales aux environs de la majorité des entreprises piscicoles. Relativement peu de pisciculteurs ont cependant indiqué si la présence de ces espèces animales s'était accrue ou avait diminué depuis l'implantation des piscifactures. Ainsi, il est impossible de déterminer si l'établissement des entreprises a occasionné le déplacement de la faune.

Seul un certain nombre de piscifactures ayant signalé la présence d'espèces animales ou de groupes d'animaux ont connu des difficultés avec ces animaux. La loutre commune, le phoque, le vison, l'otarie et le grand héron ont été les plus fréquemment mentionnés; plus de 50 pour cent des personnes interrogées ont signalé des problèmes avec chacune de ces espèces.

La prédation, particulièrement de la part des loutres communes et des phoques, est le plus fréquent des problèmes mentionnés. Toutefois, le nombre de piscifactures qui signalent des pertes réelles est inférieur au nombre de celles qui ont indiqué des problèmes, ce qui laisse supposer que certains exploitants se fondaient sur les possibilités de pertes plutôt que les pertes réelles ou sur le stress causé par la présence de ces prédateurs pour signaler des problèmes de prédateurs. D'autre part, le pourcentage de pisciractures qui ont perdu du poisson à cause de la présence de prédateurs correspond ou est supérieur au pourcentage d'exploitants qui ont fait état de graves problèmes de prédation, ce qui laisse supposer que certains pisciculteurs estiment que la prédation est un problème mineur, même s'ils ont accusé certaines pertes.

Les pertes totales par prédation étaient de l'ordre de 105,000 poissons au cours de l'année qui a précédé le sondage, les phoques et les loutres ayant causé des pertes de 58,000 et de 30,600 poissons, respectivement. En outre, quelque 40,000 poissons se sont échappés par les brèches que les phoques, les otaries et les loutres communes ont faites dans les filets. Si l'on extrapole à partir de ces données, le total des pertes liées à la présence de la faune au cours de la dernière année serait de 147,000, dans le cas de poissons perdus par prédation, et de 61,000, dans le cas des poissons échappés. Cela outre, 8 piscifactures ont signalé des dommages causés à l'équipement par les animaux sauvages (surtout les loutres et les visons). Le montant des dommages était de 21 785 $.

Il était rare que les mammifères s'empêtraient dans les filets des piscifactures qui ont répondu au sondage. Dans la plupart des cas signalés. Il s'agissait d'oiseaux, notamment des grands hérons, des martins-pêcheurs d'Amérique et des canards plongeurs. Les données recueillies n'ont pas permis de déterminer le nombre d'animaux qui ont succombé. Par contre, les discussions avec les pisciculteurs nous ont permis de déduire que leur pourcentage était faible.

Un certain nombre de caractéristiques des piscifactures pouvaient être à la source des problèmes de cohabitation avec la faune: taille et âge des exploitations, structure des enclos, taille et espèces de saumon élevées, proximité des colonies ou groupements d'animaux sauvages, méthodes de gestion des lieux, et grosseur et couleur des mailles du filet. Compte tenu de ces facteurs, des résultats de sondage et des discussions avec les exploitants, un certain nombre de recommendations visant à mieux harmoniser la cohabitation avec la faune sont formulées.

* Il faut tenir compte de l'emplacement des colonies, des échoueries et des zones d'hivernage des phoques et des otaries, ainsi que des colonies d'oiseaux, lors du

processus de planification et d'approbation des piscifactures.

* Les méthodes de lutte contre la prédation doivent d'abord être envisagées comme mesures préventives plutot que comme mesures palliatives adoptées une fois le problème apparu. Les équipements tels les filets anti-prédateurs, les filets suspendus et les clôtures électriques devraient être installés au début des opérations, ce qui permetraient d'empêcher les animaux de déevelopper des comportements de prédation face aux piscifactures.

* Il faut régulièrement vérifier les dispositifs de lutte contre les prédateurs, les entretenir, et y consacrer le temps et l'argent nécessaires pour les garder en bon état.

* L'emploi de bonnes techniques d'élevage adoptées pour protéger la santé du poisson permet également d'éloigner les prédateurs. On pourra réduire l'attrait des piscifactures en entreposant la nourriture dans des contenants scellés ou des remises et en retirant fréquemment des enclos les poissons morts.

* Les seines et les filets à double fond offrent la meilleure protection possible contre les phoques et les otaries. L'utilisation de bombes spéciales concues pour éloigner les phoques et le tir semblent efficaces si on y a recours avant que les animaux ne développent un intérêt permanent pour la piscifacture. Les signaux acoustiques sous-marins sont efficaces au départ, mais leur efficacité diminue après deux ou trois ans d'usage.

* Les filets suspendus ou une combinaison de filets suspendus et de clôtures en mailles bordant les passerelles sont efficaces pour contrer les loutres communes et les visons. Les clôtures sont également très utiles si elles sont bien installées et entretenues.

* Les filets suspendus ou autres dispositifs similaires constituent la principale mesure de prévention contre les oiseaux. Les mailles doivent être de trois pouces ou moins et le filet doit être bien tendu et placé bien au-dessus de la surface de l'eau (plus d'un mètre). Les filets suspendus de couleur vive sont plus facilement vus par les oiseaux, ce qui réduit les risques que les oiseaux s'empêtrent dans les filets. Les fils, ficelles ou cordes suspendus suffisent probablement, s'ils sont placés de 0,5 à 1 mètre

d'intervalle, pour protéger le poisson contre les attaques des aigles, des aigles-pêcheurs et des autres oiseaux de proie.

* Les filets sous-marins constituent le meilleur moyen de protéger les poissons contre les oiseaux plongeurs. Il est recommandé d'employer un filet dont les mailles sont de moins de 4 po, pour éviter que les oiseaux ne s'empêtrent dans le filet.

1. INTRODUCTION

1.1 Purpose

This study addresses concerns arising from interactions between wildlife and salmon farming in British Columbia, many of which are detrimental to wildlife, salmon farms, or both. The specific objectives of the study are:

1) to gather information on the nature and extent of interactions between wildlife and salmon farms and the problems that these interactions create.

2) to assess the effectiveness of methods used by salmon farmers in avoiding, reducing or eliminating problems with wildlife.

3) to identify factors that reduce or, conversely, contribute to negative interactions between wildlife and salmon farms.

4) to make recommendations as to appropriate planning, management and husbandry measures for avoiding or alleviating problems with wildlife.

1.2 Salmon Farming in B.C.

The number of operating salmon farms in B.C. has grown from 10 in 1984 to 121 in 1988 (Figure 1-1). As of May 1988, an additional 53 farms had been approved, 147 applications for farm sites were under consideration and 157 permits to investigate potential sites for fish farms had been issued (B.C. Ministry of Agriculture and Fisheries, 1988; B.C. Ministry of Forests and Lands, 1988). Total production in 1987 was about 850 tonnes, over double the 1986 production level of 397 tonnes; 1988 production levels are expected to be about 5000 tonnes. Production is expected to reach 15,000 tonnes by 1990 (Deegan, 1988).

Salmon farms now occupy some 940 ha of Crown land and foreshore area, a 232% increase in land use since 1986. The Sechelt Peninsula-Sunshine Coast region was initially the major area of development, but with increasing farm density and conflicts with other coastal resource users, attention has since shifted to Vancouver Island and more northern parts of the B.C. coast.

1.3 Effects of Wildlife on Salmon Farms

There is a strong tendency for wildlife and salmon farming to overlap in their use of coastal resources. Salmon farms are typically established in sheltered coastal areas that are subject to good current flows and stable temperature and salinity regimes. These same areas tend to be environmentally productive and

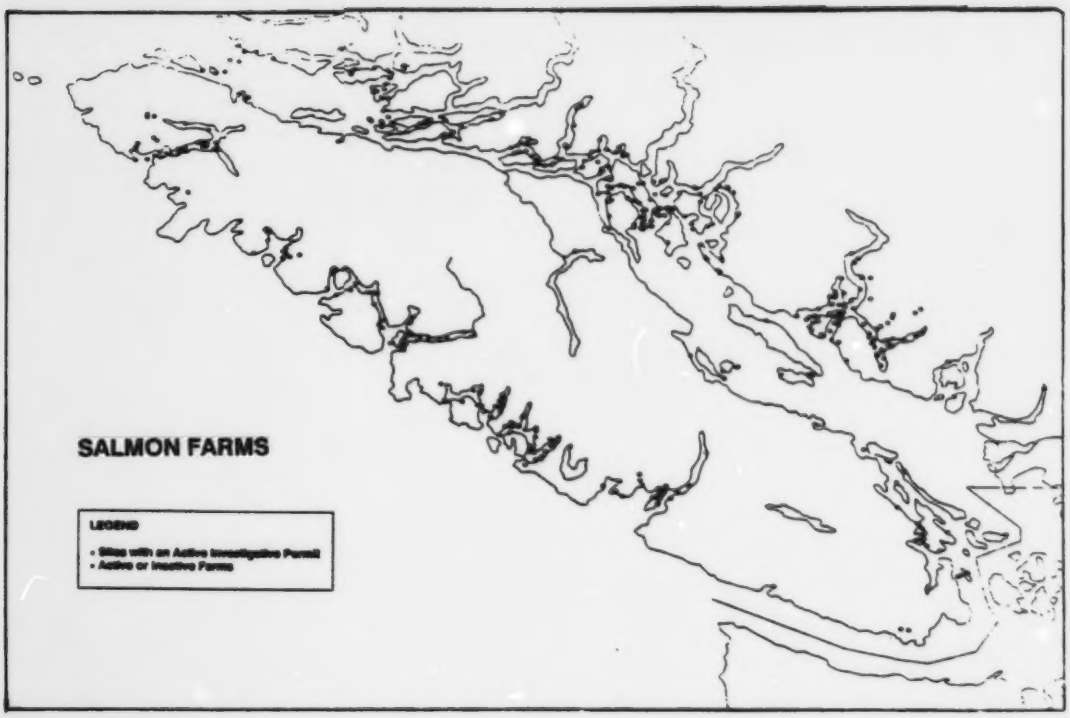

Figure 1-1: Salmon farms in southern British Columbia as of May, 1988

therefore also provide favourable habitat for wildlife. Salmon farms may further attract wildlife by providing a concentrated supply of food in the form of penned stock as well as wild fish attracted to the netpens by fish food.

The most obvious impact that wildlife can have on fish farms is loss of fish through predation. This can be in the form of direct losses where a predator actually takes fish, or through indirect losses where fish are stressed by the presence of wildlife. Physical injury, such as bite wounds or scale loss, is one form of stress. Such injuries can weaken fish and serve as points of entry for pathogens, as well as reduce the commercial value of the fish (Quebec Dept. of Recreation, 1987; Beveridge, 1986). The presence of predators around net pens can also disrupt normal swimming and foraging behaviour; physiological responses to this type of stress may lead to lowered resistance to disease and heighten the potential for epidemics among caged fish (Quebec Dept. of Recreation, 1987; Ross, 1988). Stress-induced effects, however, are difficult to gauge consistently due to the many other factors that can come into play; for instance, general health of the stock and differences in response among different salmon species to the presence of predators.

Wildlife may also damage equipment by tearing, biting or chewing through nets. The costs for repairing this equipment may be relatively small, but loss of fish escaping through holes in netpens can be significant. Finally, wildlife can also be a nuisance around the site by breaking into fish feed bags or defecating on farm structures.

1.4 Effects of Salmon Farms on Wildlife

Fish farmers attempt to deal with problem wildlife in three ways (Ross, 1988):

a) by using structures that form visual or physical barriers between predators and caged fish; e.g., underwater predator nets and top nets.

b) by using visual or auditory deterrents or other forms of harassment to discourage wildlife from coming near farms; e.g., dogs, chasing, seal bombs, underwater acoustics.

c) by removing predators through shooting or trapping.

These measures can take a toll on local wildlife populations. Efforts to get rid of predators or nuisance wildlife can significantly reduce local wildlife populations. Also, animals and birds may become entangled in anti-predator nets and suffer injuries or death. This is detrimental not only to wildlife but also to fish farms as entanglement compounds net fouling problems.

Dealing with predators, however, poses economic, legal and ethical problems. Considerable time, effort and money can be spent on counteracting predator problems because inadequate protection from predation or from other effects of wildlife can lead to substantial losses. At the same time, there are laws in place to regulate and protect wildlife from being shot, trapped or harassed. Furthermore, there is growing public opposition to what may appear to be indiscriminate use of destructive predator control measures.

A final concern is that rapidly expanding aquaculture development may displace wildlife from prime habitat. Many of the environmental characteristics that are favourable for salmon farming are also ones that provide food and shelter to mammals and birds that inhabit coastal areas. The displacement question, however, is difficult to address without detailed records of wildlife numbers and distribution both before and after aquaculture development.

1.5 Organization of this Report

Chapter 2 describes the methods (a questionnaire survey) used in the study. Chapter 3 discusses results that are general to all wildlife species covered. Chapters 4 to 7 then present and analyze the results as they apply to four main wildlife groups: marine mammals (seals and sea lions), furbearers (river otter and mink), aerial birds and diving birds. Topics covered for each of these groups include:

- distribution and feeding habits in B.C.
- frequency of occurrence around the farms surveyed.
- problems encountered at the farms with these species/groups.
- methods used to counter the problems.
- comparison with problems and methods used elsewhere to deal with similar species.

The final chapter summarizes the conclusions and recommendations resulting from the study.

2. METHODS

2.1 Questionnaire

A questionnaire (Appendix 1) was designed to gather information on:

i) the occurrence of wildlife species around salmon farms.

ii) the nature of interactions with wildlife, whether the interactions are a problem to farm operation, and if so, the magnitude of the problem from the perspective of the operator.

iii) the measures and equipment used to counteract problems with wildlife and whether the respondents feel they are effective.

iv) the costs of problems associated with wildlife and of measures used to avoid or mitigate them.

v) site characteristics (location, size, age, etc.) that may be factors in problems with wildlife.

Copies of the questionnaire were mailed to 87 salmon farming companies, most of which were members of the B.C. Salmon Farmers Association. The questionnaire was accompanied by a covering letter explaining the purpose of the project and assuring confidentiality. Three to four weeks after mail-out, company offices and/or farm sites were contacted by phone to ensure that the questionnaire had been received and was understood. In a few cases, the questionnaire was filled out over the telephone. Finally, farm sites were visited and questionnaires filled out in person if the site had a particularly serious or interesting problem or method of dealing with wildlife-related problems, the site was relatively accessible and the company agreed.

2.2 Topics Covered

2.2.1 Characteristics of farms

Respondents were asked to indicate the name of the company, location of operation, and number of years the respondent had worked in salmon farming and on the site. Certain characteristics of fish farms may influence the attractiveness of a site to wildlife, the ease with which salmon stocks can be protected, and the level of interactions that may result. Accordingly, information on the age of the farm site, the number and total volume of net pens, the species and year classes of salmon raised (indicating major and minor species on the basis of numbers of fish of each species) was requested. Additional information obtained during site visits included the types and sizes of net pens,

biophysical characteristics of the sites and the location of netpens relative to other farm facilities and the shoreline.

2.2.2 Occurrence of wildlife

The questionnaire presented 14 mammal and bird species or species groups (Table 2-1). Farm operators were asked to record whether they saw these species/groups in each season on the following basis:

- regularly (every day).
- frequently (2-6 times per week).
- occasionally (less than once per week)
- never.

They were also asked if the frequency of occurrence had changed for any of the species/groups since the farm was established or over the course of their observations. This question was an attempt to determine whether farms were attracting animals to the site (frequency of occurrence would increase) or displacing animals from their natural habitat (frequency of occurrence would decline).

2.2.3 Problems with wildlife

Five categories of wildlife-related problems were listed in the questionnaire:

- predation;
- damage to nets;
- entanglement and drowning in nets;
- getting into fish feed;
- other problems.

Operators were asked to indicate which categories of problems were encountered on their farm with each wildlife species/group, and to indicate the severity (high or low) of the problem. They were also asked to record the number of fish lost during the last year to predation and through equipment damage, and the costs associated with damaged equipment. For predation problems, they were asked to indicate the size of fish taken and the time of day of attacks for each predator species/group.

2.2.4 Methods for dealing with problems

Fifteen methods for preventing or eliminating wildlife-related problems were presented in the questionnaire. The methods were matched to 6 categories of wildlife: seals, sea lions, river otter and mink, raccoon, aerial birds, and diving birds. Respondents were asked to indicate which methods they used to deal with problems (primarily predation) associated with each category of wildlife, and to rate the effectiveness of that method in preventing or stopping predation by that category of predator. The rating

MAMMALS:	
Seals (Harbour)	*Phoca vitulina*
Sealions (Steller and California)	*Eumetopias jubatus, Zalophus californianus*
River otter	*Lutra canadensis*
Mink	*Mustela vison*
Raccoon	*Procyon lotor*
BIRDS:	
Great Blue Heron	*Ardea herodias*
Belted Kingfisher	*Megaceryle alcyon*
Bald Eagle	*Haliaeetuss leucocephalus*
Gulls (Glaucous-winged, Herring, Bonaparte's)	*Larus* sp. (*L.glaucescens, L. argentatus, L.philadelphia*)
Cormorants (esp. Double-crested, Brandt's)	*Phalacrocorax* sp. (*P.auritus, P.penicillatus*)
Grebes (esp. Western)	*Aechmophorus occidentalis*
Loons (esp. Common, Arctic)	*Gavia* sp. (*G.immer, G.arctica*)
Diving ducks (Scaup, Scoters, Goldeneye, Bufflehead, etc.)	*Aythyinae* fam.
Dabbling ducks (Mallard, Teal, Widgeon, Shoveller, etc.)	*Anatinae* fam.
Alcids (Murre, Murrelets, Auklets)	*Alcidae* fam.

Table 2-1: Mammal and bird species/groups covered in the survey

categories were:

- High - problem eliminated;
- Medium - successful in reducing but did not completely eliminate problem;
- Low - limited success in reducing problem;
- None - no effect.

Where a respondent reported using a method but did not indicate a rating, the latter was recorded as "not stated". Space was also provided for respondents to comment on methods not contained in the list given in the questionnaire. Where nets were used as a predation prevention measure, respondents were asked to indicate the mesh size, gauge, colour and material. Finally, respondents were asked how much they would be willing to pay for an effective wildlife protection method and what percent of the gross annual sales of the farm that amount represented.

2.3 Data Organization and Storage

The information from the returned questionnaires was entered into a computer database which provided ready data storage,

retrieval and analysis. To ensure confidentiality, response information was identified only on the basis of the identification number allocated to each returned questionnaire.
For the purposes of data organization and to allow for assessing regional differences in problems and methods, the responses were categorized and given an identification number on the basis of 4 regions (Figure 3-1):

1) Sechelt Peninsula and Sunshine Coast.
2) southern Vancouver Island.
3) northeastern Vancouver Island and northern mainland coast.
4) northwestern Vancouver Island.

3. GENERAL RESULTS

3.1 Response to Questionnaire

A total of 70 questionnaires covering 73 farm sites were received from 54 (62%) of the 87 companies to which they sent (Figure 3-1). This represents 42% of all sites that were approved as of May 1988, and probably greater than 50% of all operating farms at the time of the survey. However, sample sizes (n) for the topics covered in the survey vary from the total number of farm sites (73) for several reasons: not all questions were answered by all respondents; several sites that are managed by one company and are in the same vicinity were treated as one site for certain topics covered by the questionnaire; or some information was obtained only from site visits and not from mailed-in responses. Of the 70 questionnaires, 40 were completed from site visits, 26 from mailed-in responses and 7 by telephone.

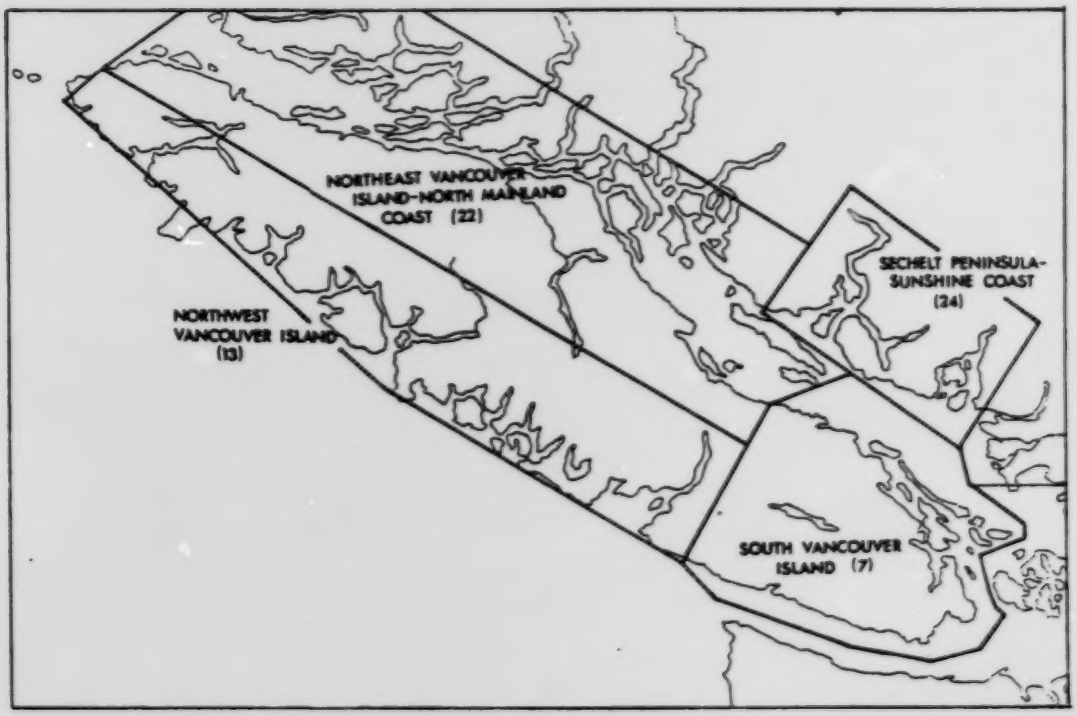
NORTHEAST VANCOUVER ISLAND-NORTH MAINLAND COAST (22)
SECHELT PENINSULA-SUNSHINE COAST (24)
NORTHWEST VANCOUVER ISLAND (13)
SOUTH VANCOUVER ISLAND (7)

Figure 3-1: Regional coverage of salmon farm sites surveyed. Numbers in parentheses indicate the number of sites covered in that region.

3.2 Profile of Salmon Farms Surveyed

3.2.1 Experience of respondents

Half of the respondents had worked on salmon farms for less than 2 years, and only 54% had worked on their particular farm site for more than 1 year (Figure 3-2). These characteristics reflect the youth of the salmon farming industry in B.C. They also indicate that few of the respondents to the survey had long-term experience with wildlife around their farms.

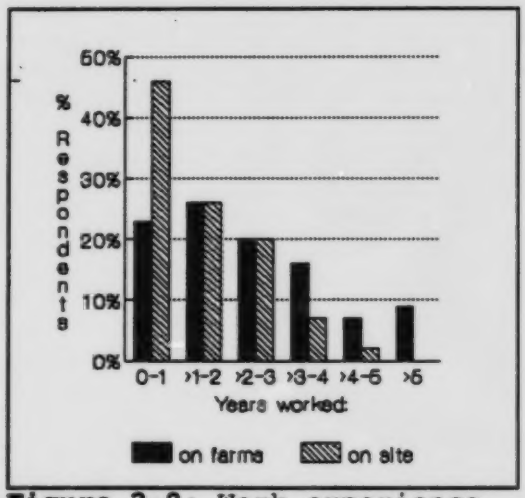

Figure 3-2: Work experience of respondents (n=73)

3.2.2 Characteristics of farms

Age: The median age of fish farms surveyed was 2 years old (Figure 3-3). Farms in the Sechelt area tended to be older than those on Vancouver Island.

Size: Most farm sites consisted of 10-20 netpens; the mean was 18.7 pens/site (Figure 3-4). Total pen volume per farm site averaged 35,933 m^3; most sites were less than 60,000 m^3 (Figure 3-5).

Netpen characteristics: Most farms surveyed used pens that were 750-3500 m^3 in size; 10-15 m on each side and 6-15 m deep. Four types of netpen construction were identified (Figure 3-6). Galvanized steel pens occurred most frequently as the main type in use. However, many farms had more than one type in operation, and wooden pens and circular PVC pens ("polar circles") were used most frequently as secondary types. Most wooden or steel pen systems had 0.5-1 m wide walkways around the periphery of each pen or series of pens, while PVC pens usually had no walkways. In all cases, the netpens were suspended from uprights or stanchions that rose 0.75-1 m above the surface of the water.

Fish stock characteristics: Chinook salmon was raised as the major crop on 73% of the farms surveyed; 23% raised Coho, and 4% raised Atlantic salmon or Steelhead (Rainbow trout) as major crops. Coho and Steelhead were the favoured species for minor crops (Figure 3-7). Year class is an indicator of the size of fish present on

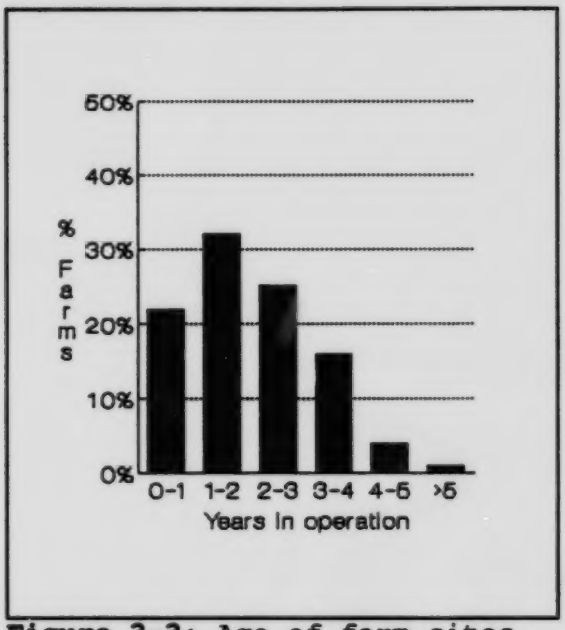

Figure 3-3: Age of farm sites surveyed (n=73)

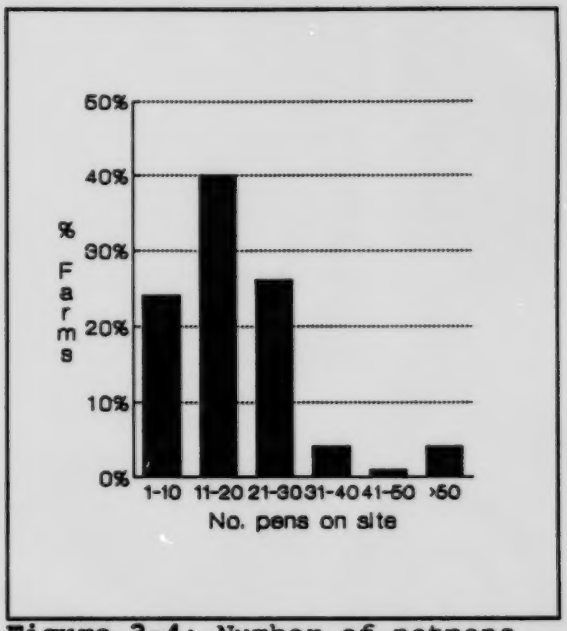

Figure 3-4: Number of netpens at sites surveyed (n=69)

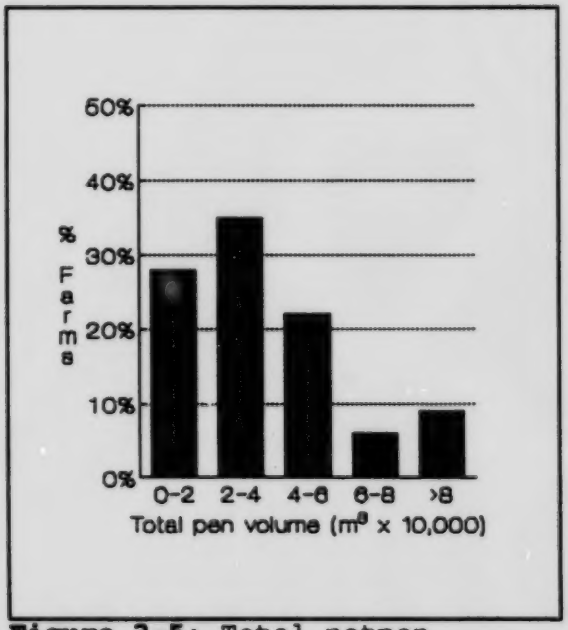

Figure 3-5: Total netpen volumes at sites surveyed (n=68)

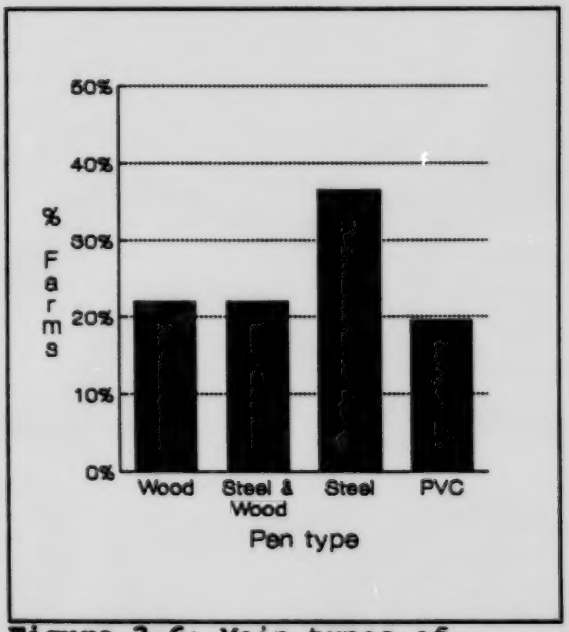

Figure 3-6: Main types of netpens used at sites surveyed (n=41)

the site[1]. The majority of fish were 1986, 1987 and 1988 stock (Figure 3-8). On average, 1988 stock were less than 500 g, 1987 stock were 1-2 kg, and 1986 stock were 2-5 kg. Fish of 1984 or 1985 year class were often 10 kg and over, and were held almost exclusively as broodstock.

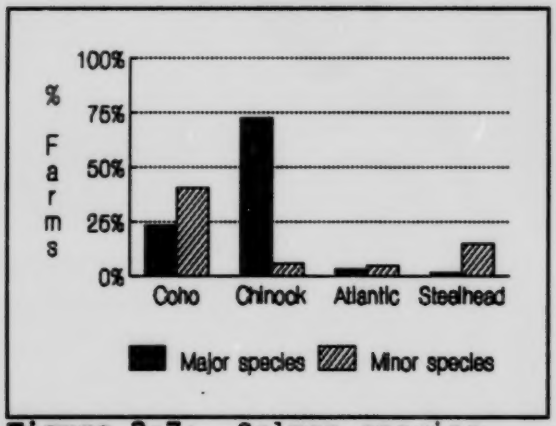

Figure 3-7: Salmon species raised at sites surveyed (n=69)

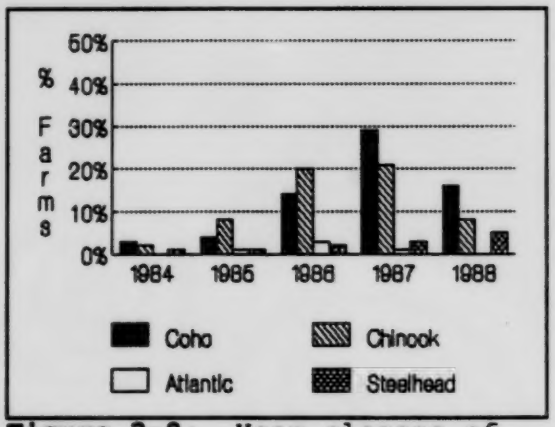

Figure 3-8: Year classes of salmon raised at sites surveyed (n=69)

3.2.3 Comparison with other countries

Chapters 4-7 draw comparisons between wildlife-related problems that are experienced in B.C. with those in other countries. Some of the differences in problems may be related to differences in characteristics of salmon farms such as the age of the industry, the size and configuration of sites, the species raised, and stocking densities.

Salmon farming has a longer history in Norway and Scotland, where it began on an experimental basis in the 1960's. With most techniques worked out by the late 1970's the industry rapidly grew in both countries. There are currently some 750 salmon farms in Norway that produced an estimated 74,000 tonnes in 1988 (Chettleburgh, 1988). Scotland has 113 companies operating 157 sites that produced about 16,000 tonnes in 1987 (Institute of Aquaculture, 1988). By comparison, B.C. produced about 5000 tonnes in 1988.

Farm sites tend to be smaller in Norway and Scotland than in B.C. In Norway, farms are restricted under legislation to a

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[1] Year class was defined as the year that the fish were transferred to salt water.

maximum total pen volume of 8000 m^3, substantially smaller than the farms surveyed here which averaged 36,000 m^3. There are no restrictions on the Scottish mainland, but there are tonnage limits to salmon farms in the Western Isles (50 t) and Shetland Islands (100 t). Although 69% of sites in Scotland produce less than 50 tonnes/year, most of the national production comes from sites producing over 1000 tonnes/year.

There are also differences in farm construction. In Scotland, netpens are typically much smaller (averaging 250 m^3) and shallower than the netpens used by farms surveyed in B.C. While most farms surveyed in B.C. suspended netpens from stanchions that were 0.75-1 m high, in Scotland, netpens are often suspended directly from the walkway such that the tops of the netpens are less than 0.5m above the surface of the water. "Polar circle" pens dominate the salmon farm industry in Norway (Institute of Aquaculture, 1988) but are less common in B.C. and Scotland.

Norwegian salmon farms operate at stocking densities of 10-15 kg/m^3 (Chettleburgh, 1988), considerably greater than the 4-8 kg/m^3 practised in B.C. (B.C. Ministry of Agriculture and Fisheries, 1988). This is partially in response to restrictions in farm size and partially due to differences in salmon species that are raised. Norway and Scotland raise Atlantic salmon exclusively, whereas Atlantic salmon are a minor crop in B.C. compared to Pacific species. Atlantic stocks are less stressed by high density conditions than are Pacific stocks, due to differences in species characteristics as well as their longer history of domestication.

3.3 Frequency of Occurrence of Wildlife

Almost all farms reported the occurrence of the 14 wildlife species/groups listed in the questionnaire. However, relatively few indicated whether the frequencies of these occurrences have changed since the farms were established. For example, of the 63 operators who observed seals around their farm, only 22% indicated any change in the frequency of their occurrence; response levels were lower for all the other species/groups. Whether the low response rate means that the frequency of occurrence had not changed in the opinion of the respondent or that the respondent did not know if any change had occurred is uncertain. Site visits suggested that in many cases, operators had not closely observed the presence of wildlife around their farms unless the animal was perceived as a threat. In a few cases, the operator stated that the frequency of occurrence of some wildlife species had declined as a result of actions taken (shooting, trapping, etc.) to get rid of them.

Very few respondents indicated the occurrence or experienced any problems with raccoons; hence, this wildlife category was eliminated from our analysis.

3.4 Problems with Wildlife

The definition of a wildlife-related "problem" and the measurement of its severity was a subjective judgement on the part of the respondent. Three main factors appeared to affect a respondent's perspective of a "problem":

- loss in terms of number of fish. This was the main yardstick of problem severity, tempered by loss in biomass. For example, loss of 10 smolts to a heron would be considered less serious than loss of a 2-year-old fish to a river otter.

- frequency of the problem. If the problem occurred for only a short period of time (e.g., when a species passed through during migrations), many respondents categorized the severity as low. In some cases, however, it was noted that one visit by an aggressive migrating sealion could result in higher losses than several visits by a resident river otter or mink over a year. In these situations, a respondent may have rated the problem as severe.

- attitude of the respondent. Some operators appeared to be quite unconcerned by the presence of wildlife around the farm, while others indicated considerable anxiety at the potential (though not necessarily realized) threat that such presence suggests. The latter was more prone to consider any loss as severe, whereas the former may tolerate a certain low level of predation or stress.

Only a proportion of farms that reported the presence of a wildlife species or group experienced problems with that species/group (Figure 3-9). These proportions were greatest for river otter, seals, Great Blue Herons and Belted Kingfishers; over 80% of the respondents reported the presence of these species and over 50% cited some sort of problem with them. This does not indicate the nature or severity of the problems encountered with these species, which are discussed in the chapters 4-7.

Predation was the most commonly cited problem in the survey. However, for all wildlife species/groups, the number of farms reporting actual losses of fish was less than the number that cited predation problems (Figure 3-10). This supports the notion that some operators considered predation a problem on the basis of potential rather than actual predation. On the other hand, the percentages of farms that lost fish were the same or greater than those reporting a <u>severe</u> problem. In some cases, therefore, operators view predation as a minor problem even though they experience some losses. There was a close correspondence between the number of farms that lost over 100 fish in the last year and the number that considered their predator problems to be severe.

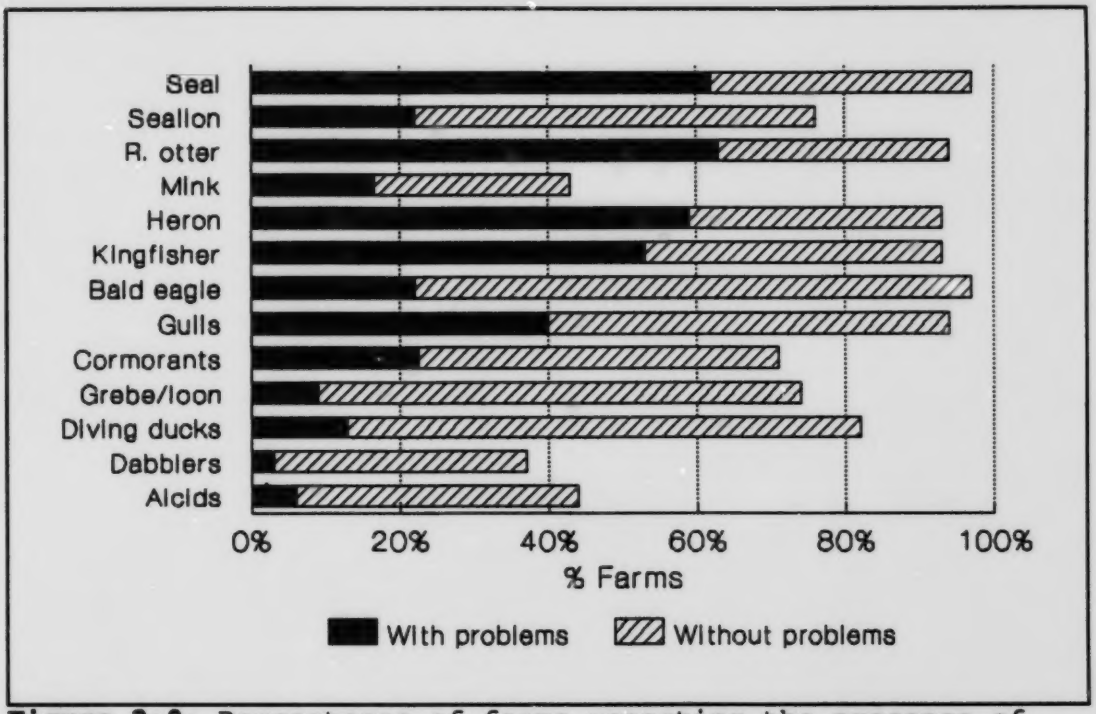

Figure 3-9: Percentages of farms reporting the presence of and problems with wildlife (n=68)

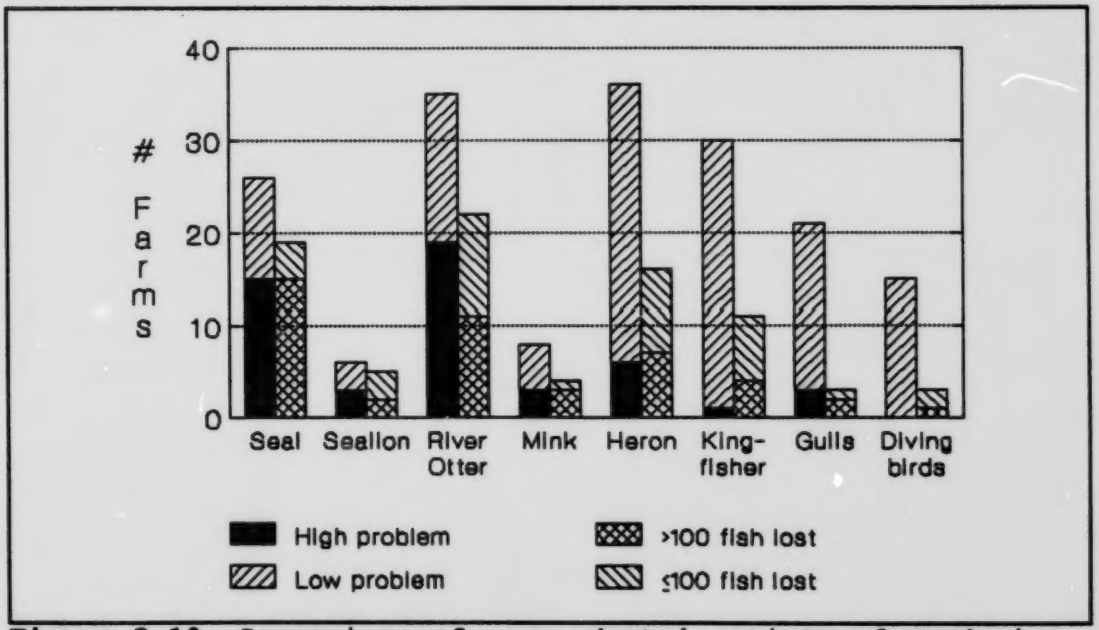

Figure 3-10: Comparison of respondents' ratings of predation problems (high/low) with reported losses of salmon to wildlife

Although, the questionnaire did not present stress as a problem category, 20 respondents identified stress as a problem in its own right. Some proportion of losses to predation (Figure 3-10) includes losses perceived to be stress-induced. This may help explain why some respondents cited predation problems even though they did not experience direct losses to predation; predators may not have been successful in actually taking fish, but respondents may have felt that the attempted predation was having serious detrimental effects on their fish stocks.

3.5 Methods Used to Deal with Problems

Most farms used several methods in combination to deal with one or more types of predator (Figure 3-11). An earlier survey of 15 salmon farms in B.C. found that 56% used no measures to protect their stock from underwater predators, although 80% did use top nets (Aylard, 1986). Comparisons to the results of this survey suggest that farm operators in B.C. have generally increased the level of protection against predators. Individual methods and their effectiveness are discussed in chapters 4-7.

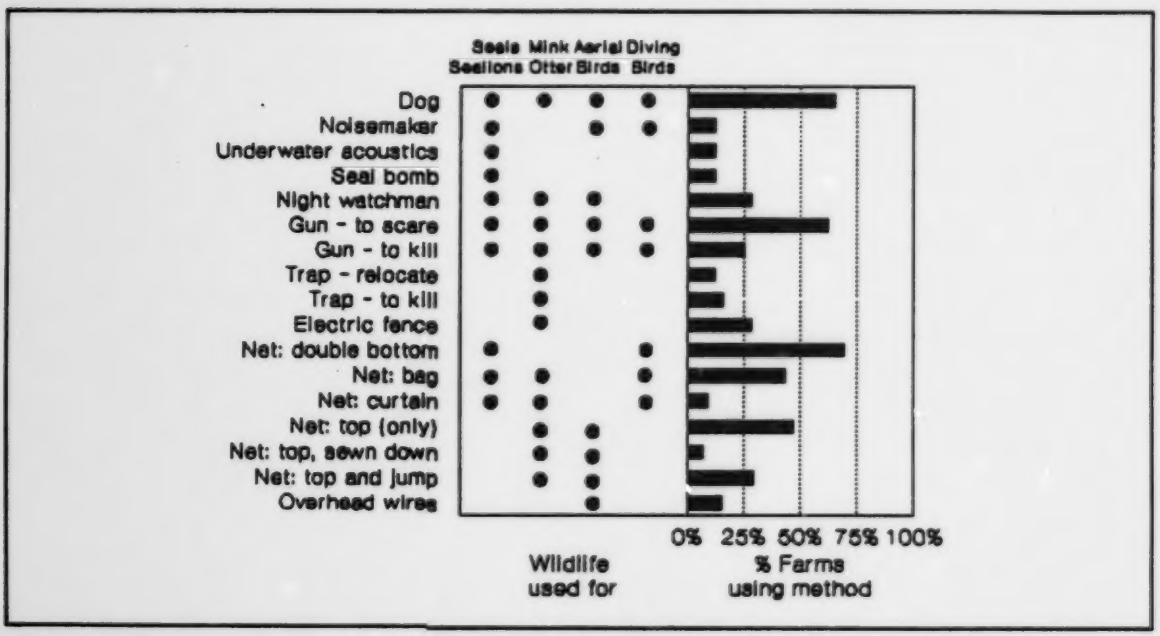

Figure 3-11: Frequency of use of predator prevention methods and the wildlife groups for which they are used (n=68)

4. SEALS AND SEA LIONS

4.1 Background: Distribution and Feeding Habits

4.1.1 Harbour Seal

The harbour seal (*Phoca vitulina*) is the most abundant marine mammal in B.C. With an annual increase of 12.5% since the early 1970's, the current population is estimated at 75,000 animals, near historically high levels for the province (Olesiuk and Bigg, 1988).

Harbour seals prefer nearshore and estuarine environments, although they will enter freshwater. Tidal reefs, boulders, sandbars and log booms are favoured haulouts. Harbour seals are non-migratory, generally showing high fidelity to haulout sites and breeding areas (Jefferies, 1986). Breeding season peaks in May/June in northern B.C. and in July/August in southern B.C. (Olesiuk and Bigg, 1988). Harbour seals do not congregate in a few concentrated areas during the breeding season; rather, breeding and pupping areas occur throughout the species' range. All age and sex categories mix freely in resting and haulout areas (Bigg, 1969). Sub-adults are the most mobile, with individual movements of up to 485 km being reported (Brown and Mate, 1983).

Feeding follows no distinct diurnal pattern (Brown and Mate, 1983), but may be tide related, becoming more intensive during ebb tides (P. Olesiuk, 1988: pers.comm.). Daily food intake averages 2-3.5 kg (4-7 lb)/adult seal, with reduced feeding during pupping (Spalding, 1964). Prey species vary with the season (Table 4-1); salmon may constitute 5-10% of the total diet (P. Olesiuk, 1988: pers. comm.). Vision may not be as important in prey search as originally believed, since successful feeding occurs in waters of very low visibility and blind seals have been found in well nourished condition in the wild (Shaffer and Slipp, 1944). In B.C., there is evidence that seals concentrate at certain river mouths during salmon and eulachon runs (P. Olesiuk, 1988: pers.comm.). In other areas, however, it has been shown that peak seal concentrations coincide more with local peak abundances of other prey such as smelt, shiner perch and herring than with salmon runs (Brown and Mate, 1983).

4.1.2 Sea lions

Steller sea lion: Of the 2 sea lion species found in B.C., only the Steller sea lion (*Eumetopias jubatus*) breeds here. The current population in B.C. is estimated at 6-7,000 animals, approximately one-third of historical population levels (Bigg, 1985). This population undergoes a seasonal redistribution (Table 4-2). In the breeding season (June/July) greatest numbers are found on the rookeries, with some occupying year-round haulouts. During the rest of the year, animals disperse to numerous winter sites. Total numbers are greatest during the winter, likely due

	SUMMER	WINTER
Harbour Seal	sculpins, flatfish, hake, rockfish, greenling, smelt, surf perch, herring, salmon, octopus	hake, squid, herring, herring, octopus salmon
Steller sea lion	octopus, rockfish, dog-fish, salmon, squid, flatfish, pollock, sandlance	herring, hake, squid, pollock, dogfish salmon, flatfish, eulachon
California sea lion	-	herring, hake, squid, octopus, salmon, dog-fish, pollock, eulachon

Table 4-1: Diet of seals and sea lions in B.C. (from Olesiuk and Bigg, 1988; Spalding, 1964)

TYPE	LOCATION	SEASON	COMPOSITION
Rookery	exposed to ocean swell, far from land	summer (peak July); a few year-round	cows, pups, bulls, some juveniles
Year-round haul-out	exposed to ocean swells, close to land	year-round; steady occupancy	mixture of ages & sexes, little seasonal change
Winter haul-out	- semi-exposed & close to land - sheltered inlets	fall, winter, spring	- bulls, cows, young - mixed, or adult & sub-adult males
Winter rafting sites	sheltered inlets, close to land	fall, winter, spring	same as winter haulouts

Table 4-2: Types of Steller sea lion concentrations in B.C. (from: Bigg, 1985)

to in-migration from other breeding areas by animals in search of food (Bigg, 1985). Sub-adults have been known to move up to 1500 km from their place of birth (Olesiuk and Bigg, 1988). When reproductively mature, most animals return to their rookery of birth.

Sea lions feed primarily at night (Spalding, 1964). Adult females consume 5-10 kg/day; adult males, 10-20 kg/day (Olesiuk and Bigg, 1988). Like seals, their diet varies seasonally (Table 4-1). Food intake decreases for reproductive cows during the pupping season (June), and for territorial males during the breeding season (July). Overall, salmon constitute only a few percent of the total diet (Olesiuk and Bigg, 1988).

California sea lion: The California sea lion (*Zalophus californianus*) does not breed north of 38° latitude, and only adult and subadult males venture to the B.C. coast during the non-breeding season (Olesiuk and Bigg, 1988). Local occurrence is usually limited to September-May and to the southern half of Vancouver Island. Historically rare, this species now numbers around 3000 in B.C. waters during the winter (Olesiuk and Bigg, 1988), the result more of increased northern movement of this species rather than from population growth (Bigg, 1985). California sea lions utilize the same winter haulouts and rafting sites as Steller sea lions (Olesiuk and Bigg, 1988), and their winter diet similar to that of the Steller (Table 4-1). Salmon and herring comprise approximately 10% and 35% of the diet respectively (Olesiuk and Bigg, 1988).

4.2 Frequency of Occurrence Around Salmon Farms

Seals were observed at almost all the farm sites surveyed (Figure 4-1A). Over 60% of respondents reported observing seals more than twice weekly, with little seasonal difference in the frequencies of observations. Seals were seen more frequently by farms in southern Vancouver Island and along the Sechelt/Sunshine Coast than in the NE and NW Vancouver Island regions. Only 14 (22%) respondents indicated a change in the frequency of seal occurrence; 7 observed an increase and 7 observed a decrease in seal numbers around their farm sites.

Sea lions were observed less frequently than seals (Figure 4-1B). Sea lions occurred more frequently in spring and winter and were noticeably more abundant in southern Vancouver Island than in other regions. Of the 50 respondents who reported sea lions around their site, only 10% indicated a change in their frequency of occurrence; 3 said sea lions had increased and 2 said they had decreased in number around the farm, primarily due to actions taken by the operator to get rid of them.

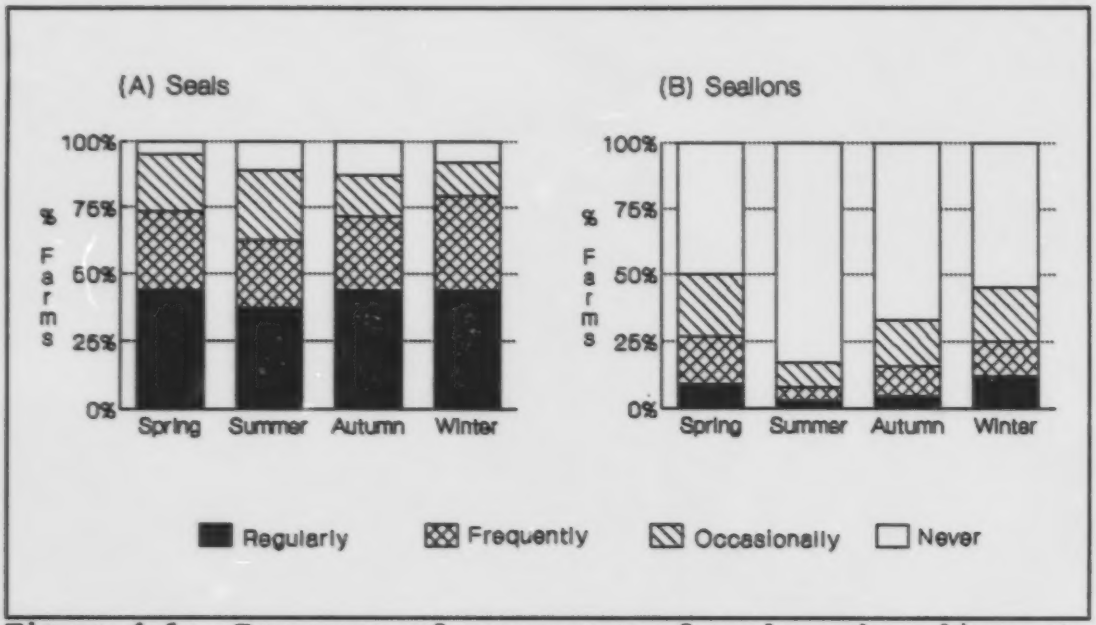

Figure 4-1: Frequency of occurrence of seals and sealions at sites surveyed (n=68)

4.3 Problems Reported by Salmon Farms

4.3.1 Predation and stress

Seals: Predation by seals was cited as a problem by 37% of the respondents; 21% classified it as severe (Figure 4-2A). Actual losses over the last year to seals were reported by 27% of the respondents (Figure 3-12). These farms reported a collective loss of 55,000 - 60,000 fish to predation or stress caused by seals (Figure 4-3). Most seal attacks were directed at fish in the 500 g-2.5 kg size range. Slightly more seal attacks occurred at dawn and dusk than at other times of day. Several operators noted that seals often suck the contents of the fish through the net, leaving head, tail and/or backbone behind.

In her study of predator problems in Scotland, Ross (1988) reports that 77% of the 47 farm operators that she interviewed cited seals as causing loss of stock or damage to equipment. She notes that "the scale of seal predation is extremely variable, from no damage over several years at some farms to the loss of tens of thousands of fish in one night at others". She describes the mode of attack by seals, which is comparable to descriptions received during interviews in this survey:

"Seals typically attack by charging at the side of the cage, causing the fish to panic and crowd into a corner or down to the bottom. The seal is then able to grasp mouthfuls of fish through the net... either at the side of the cage or more commonly, by pushing up through the cage base... Typically, a seal attack results in large numbers of fish being killed or wounded, usually by a ventral bite just behind the gills and/or claw grazes down the side." (Ross,1988: 27)

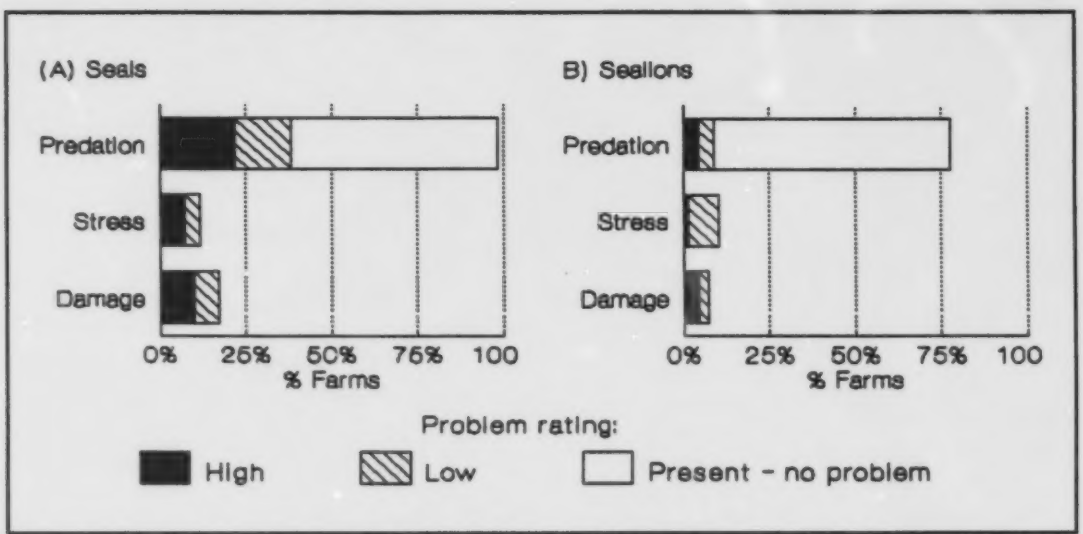

Figure 4-2: Problems with seals and sealions (n=68). "High/low" is to the rating given by respondents who experienced problem; "Present - no problem" means that the animals occurred but no problems were indicated.

Sea lions: The frequency of predation problems (Figure 4-2B) was lower with sea lions than with seals, reflecting their less frequent occurrence and more restricted distribution. Losses to sea lions were reported by five farms (Figure 4-3). Several operators noted that sea lions are most prevalent when following herring or migrating salmon into inlets or bays. They noted sea lions will swim by without showing much interest in the farm, and that only occasionally will one swim close to or charge a netpen.

4.3.2 Damage to equipment and consequent fish loss

Equipment damage was attributed to seals by 12 respondents and to sea lions by 5 (Figure 4-2). Most damage consisted of holes in underwater predator nets. Costs of repairing nets are fairly low; most operators estimated $10-20.00 for material and time to

mend the holes. However, the cost of net damage can be significant if it results in loss of fish. Three farms indicated losses of fish escaping through holes in netpens. One operator blamed seals for a collective loss of 10,000 fish to predation, injury to fish, and possible escapement through holes. Another lost 14,000 adult salmon through a large gash in the netpen; a sea lion was observed around the pen 4-6 times prior to the damage.

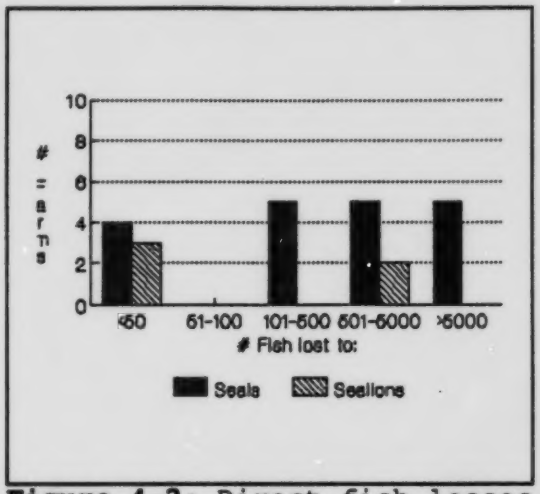

Figure 4-3: Direct fish losses to seals and sealions (n=68)

It should be noted that there are many ways in which holes can be created and go undetected. Flotsam can get caught and tear nets; semi-submerged logs may rub against nets; nets can be snagged on other equipment during installation, cleaning or as the result of heavy currents. The evidence for damage to nets by wildlife is circumstantial in most cases; for example, the remains of a fish tangled in a hole or the observation of an animal around the farm just prior to the discovery of holes in nets.

4.4 Methods Used to Deal with Predation Problems

4.4.1 Dogs

Although 65% of the respondents had dogs on their site, most of them found that dogs were of little or no use in scaring away seals or sea lions (Figure 4-4).

4.4.2 Aerial noisemakers

Use and effectiveness: Of the 8 farms that used aerial noisemakers of some type (Figure 4-4), one found them to be very effective against seals.

Discussion: The types of aerial noisemakers being employed were not indicated by the respondents using them. Small explosive shells fired from a 12-gauge shotgun, known as "cracker shells", are the most common form of aerial noisemaker used in commercial fisheries to scare marine mammals away from fishing lines (Scholl and Hanan, 1987a,b). The shell is aimed to explode just over the animal and can be fired from a range of up to 50-75 m. Cracker shells have been found to be somewhat successful in commercial fisheries in frightening sea lions and seals for short periods of time (Mate and Harvey, 1987). However, their use requires some accuracy because unless the animal has its head out of the water

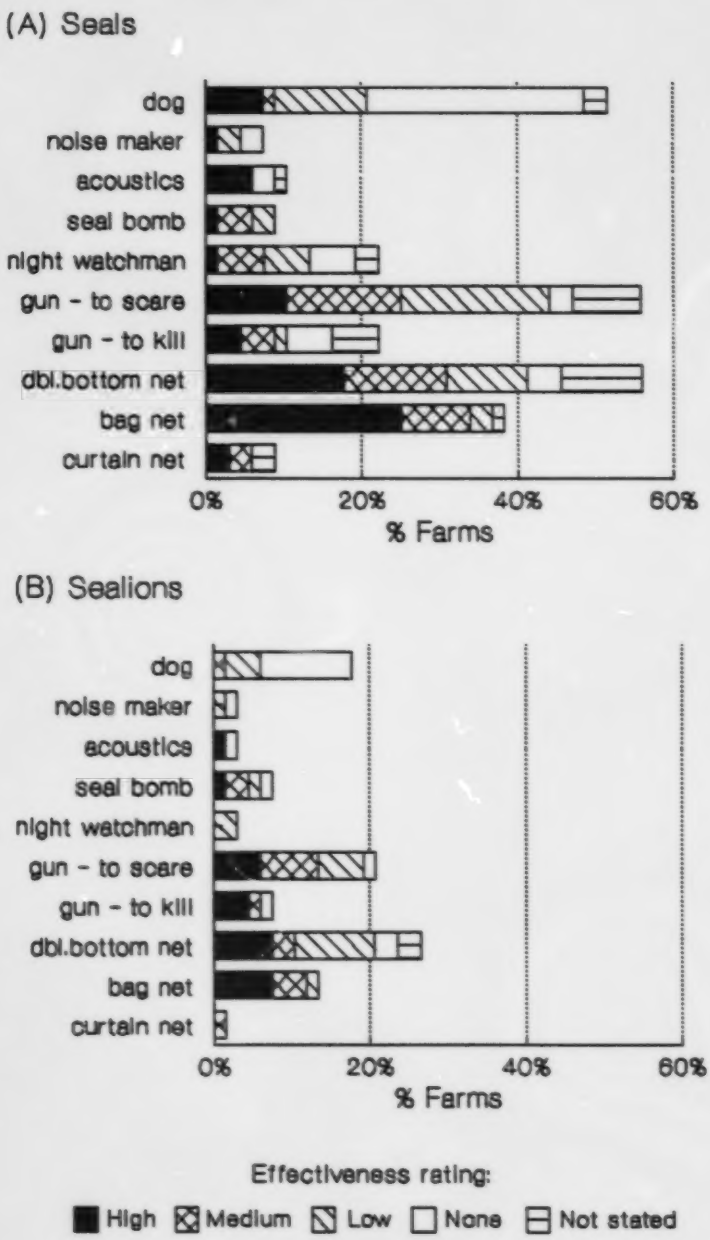

Figure 4-4: Use and effectiveness of predator protection methods against seals and sealions (n=68)

or is directly under the explosive, it may not detect it. This method suffers the disadvantages of being costly (if harassment is required over extensive periods of time), labour intensive and potentially dangerous to the user (Scholl and Hanan, 1987a). Experience in agriculture also shows that most animals can become accustomed to a noise that is repeatedly generated and eventually learn to ignore it. Another disadvantage of noisemakers is the potential irritation of neighbours. Consequently, aerial noisemakers are usually regarded as a short term solution to an immediate problem.

4.4.3 Underwater acoustics

Use and effectiveness: Eight respondents indicated that they have used or are using underwater acoustic harassment devices ("seal scarers" or AHDs) to scare off seals and sea lions (Figure 4-4). Of these, 5 found AHDs highly or very effective against seals and 1 found them highly effective against sea lions. However, the instruments had not been in operation for more than 2 months at any of the sites. One farm that had used an AHD in the past found that seals became accustomed to the sound; over time, it became a "dinner gong" rather than a deterrent.

Discussion: Underwater acoustic harassment devices were first designed to chase away harbour seals in fisheries off the Pacific Northwest (Mate and Harvey, 1987). These devices generate high frequency sounds in the order of 12-17 kHz, which lie in the range of maximum sensitivity for seals. (*ibid.*) They are not heard by fish, however, and do not affect fish egg or sperm viability (Mate *et al.*, 1987). The sounds are amplified and transmitted to a radius of 30-50 m from the underwater loudspeaker. In some models, the operator can alter the frequency and intensity of sounds as well as the pattern in which they are produced.

AHDs have been tested fairly extensively in commercial fisheries in the Pacific Northwest. Preliminary results were encouraging. For example, the use of AHDs in gill net test fisheries in the Columbia River significantly reduced the number of salmon damaged or eaten by seals (Mate and Harvey, 1987). However, the effectiveness declined with time; 4 years after initial use at an experimental hatchery, seal predation rates had returned to what they were without the AHDs (*ibid.*). Mate and Harvey (1987) suggest four possible reasons for the decline in effectiveness:

i) seals became habituated to the sounds.

ii) the AHDs became conditioning reinforcers, signalling to the seals where fish were readily available.

iii) the signals only startled the animal. The level or loudness of sound produced by an AHD is typically not great enough to

cause pain in seals or sea lions. Greenlaw (1987a) estimates that pressure levels greater than +185 dB are required to produce pain in seals. These levels would be found about 2 m away from an AHD transducer operating at 100-200 watts. To inflict pain at a range of 10 m would require a 5400 watt power source - clearly impractical to build or operate in most fish farm situations. In their present configuration, therefore, AHDs rely more on a psychological than physiological effect on seals.

iv) individual seals had impaired hearing. Even if an AHD is effective in deterring most seals, the few that are not deterred can still inflict considerable damage to fisheries and hatchery returns (Mate *et al.*, 1987).

AHDs have been used on fish farms in Norway and the U.S. for at least 2 years with some success, according to a manufacturer (Seafarm Trading, 1988). Ross (1988) reports that 8 farm operators interviewed in Scotland were using AHDs. Their views on the effectiveness of these devices were mixed: 3 operators found them to be ineffective within a few weeks, whereas others who had been operating them for 2 months or more claimed that they were still effective. One Scottish farmer claimed to achieve long term success by using an AHD in conjunction with shooting as a negative reinforcement.

In general, the short and long-term effectiveness of AHDs may be affected by a number of factors:

- *water environment*. Temperature, salinity and depth all affect the propagation of sound in water. In situations where any of these vary over a short distance or time span (e.g., changes in depth due to tides, or changing temperature or salinity layers) the way in which the sound is projected may change (Thomas, 1987). In addition, wind, rain, sea state and man-made noise can increase ambient noise levels and decrease the effectiveness of sound propagation from the AHDs.

- *bottom topography*. The type and structure of the bottom can cause sound to be reflected or attenuated so as to decrease the effective distance or loudness of sound.

- *location relative to the pens*. The loudspeaker should be located in the middle of a farm, where it can transmit its signal so as to cover all parts of the farm. Placement at mouths of inlets and small bays can also be effective if they totally block the entrance to the site. The loudspeaker should also be placed 1-2 m below the bottom of the netpens; if it is placed too close to nets or fish, the signal simply reflects off them (T. Severinson, 1988: pers.comm.).

- *characteristics of sounds generated.* There are ways of increasing the effective loudness of sounds that can be reasonably generated by an AHD. To the human ear, perceived loudness depends to some extent on the duration of a tone as well and on the number tones of which the sound is composed. The longer a tone is held (up to a limit of 1 sec.), the greater effect it has on the auditory senses. Similarly, sounds made up of several tones (frequencies) seem to be louder than single tones. Extrapolating this to seals' hearing, Greenlaw (1987) suggests using pulse lengths on the order of 0.5-1.0 seconds and transducers that can generate several frequencies of sound to increase the effectiveness of the AHD.

  Research on animal behaviour suggests that sounds should be produced in bursts with quiet intervals of random length (3-5 minutes) between the bursts (Pryor, 1987). In this way, the animal is unsure of when the next sound will occur. Operating several units, all with the burst-mode of operation, might also increase effectiveness in that in addition to being unable to predict the time when sounds will occur, the animal will be uncertain from where the sound will come (Greenlaw, 1987).

- *timing of use.* Intermittent rather than constant use of an AHD reduces the chance of seals habituating or becoming "deaf" to it (Ross, 1988). This may be effective so long as seals are driven from the site for those periods when the AHD is not in use.

- *predator motivation.* The motivation of a seal probably determines the level of discomfort it is willing to endure on a short or long term basis in order to get at a perceived food source. This motivation may be associated with general food availability in the wild.

- *regular maintenance.* For example, the user must check and service the transmitter and battery regularly.

Several operators interviewed in this survey expressed interest in trying an AHD, but were unsure of the usefulness of the technology, particularly given their high price. Single units (sound generator with 1 loudspeaker) that produce one frequency cost $2000-$3000.00. More sophisticated devices that allow the operator to choose different signal frequencies and/or program the rate and timing of bursts can cost $3-5000.

Some research has been carried out on the emission of other types of sound; for example, killer whale calls, these being the main predators of seals. This has not been effective over the long term, however, primarily because there is no negative reinforcement

accompanying the sounds and the seals learn to ignore them (Mate and Harvey, 1987).

4.4.4 Seal bombs

Use and effectiveness: Eight farms reported using seal bombs against seals and sea lions (Figure 4-4). Most used bombs as an intermittent remedial measure, throwing them when the animals are sighted close to the netpens. Most operators found this method to be effective in keeping seals and sea lions at bay but it did not necessarily eliminate their presence around the farm.

Discussion: Seal bombs are explosive devices that are thrown into the water in the vicinity of a potential predator. Most types are equivalent to approximately one-quarter stick of dynamite and cost $3-5.00. They can be purchased with varying fuse times (10-20 seconds are common) and explode at depths of 2-3 m. They produce a sound of less than 2 kHz in frequency and approximately 190 dB in loudness at the source. They also generate some light on explosion. Besides scaring the animals, seal bombs may cause auditory pain or physically damage the inner ear if they explode very close to the animals, although whether such damage does occur has not been conclusively determined (Awbrey and Thomas, 1987).

Accuracy, timing and frequency of use may be factors in the effectiveness of seal bombs. Obviously, the closer a bomb is to a seal or sea lion, the greater the effect of the explosion. Two operators noted that the animals must be underwater at the time the bomb explodes. One operator reported using seal bombs as a preventive or "predator training" measure ever since operations started, throwing them out from the corners of the netpens whenever seals or sea lions were seen approaching the site. This farm has apparently never been subject to seal or sea lion attacks despite regular sightings of the animals. In comparison, another farm started using bombs only after it had experienced several attacks by a group of seals from a nearby colony. The bombs made the seals wary but they still hung around just beyond the effective perimeter of the bombs. The operator felt that if bombs had been used initially in combination with other deterrence methods (e.g., night watchmen), the seals may have been sufficiently discouraged from coming close to the netpens before they learned of the presence of the caged fish.

The major disadvantages of seal bombs are that they are labour intensive, dangerous if improperly used, and can be expensive if used intensively over extended periods of time. They may harm the seals or sea lions at which they are directed, either by damaging auditory centres or through direct hits. There is also some concern that bombs may disturb fish because they are within their range of hearing (Mate and Harvey, 1987).

4.4.5 Night watchman

Use and effectiveness: Of the 19 (28%) farms that employed night watchmen, most found them to have some effect against seals and sea lions (Figure 4-4).

Discussion: The major factor in the effectiveness of this measure is the vigilance of the watchman. Most farms resort to constant night monitoring only when serious night-time attacks have occurred, since paying for this service on an ongoing basis is expensive. In some cases, 24-hour presence of staff on the site is a requirement for insurance. Otherwise, most farms rely on dogs or periodic night checks to warn of potential marauders.

4.4.6 Shooting

Use and effectiveness: Over half of the respondents reported using guns to scare off seals; 45% (n=38) of these users rated this method as moderately or highly effective in reducing seal problems. Fewer respondents (16%) acknowledged shooting to kill seals of which just over half found it highly or moderately effective (Figure 4-4).

As sea lions were less commonly seen around farm sites, only 21% of respondents reported using guns to scare them off, of which 64% (n=14) found it of high or medium effectiveness (Figure 4-4). Few operators (7%) reported using guns to kill sea lions, although most of those that did (80%) found it of high or medium effectiveness in alleviating problems primarily because it got rid of the rare, aggressive animal.

Discussion: Shooting is used more frequently as a scare tactic, with most operators shooting to kill only when they feel it is necessary. However, the sense of necessity differs among individuals. While some operators shoot at predators only once there is evidence of loss, damage or stress to fish, others will shoot at any wildlife that comes within sight of the farm and which they consider to be a potential threat, regardless of whether they have encountered any negative interactions with that species or not. Most operators, however, perceived the use of guns as effective only in remedying an immediate problem with one or two persistent animals; it is not a replacement for general preventive and deterrence mechanisms.

The federal *Fisheries Act* provides protection for seals and sea lions. These animals can be killed for the purpose of protecting fishing gear or to protect fish that have been caught or are being farmed only with a licence issued under the Act by the Department of Fisheries and Oceans. Penalties are as high as $5000.00. We did not ask operators whether they used guns with or without the appropriate permits. We surmise, however, that faced with a perceived, immediate threat, most operators would not delay

in taking quick remedial action regardless of company policies or permitting requirements.

The figures obtained in this survey probably underestimate the use of guns on salmon farms. There is understandably considerable reluctance to divulge this type of information for fear of recrimination. This reluctance was intensified by a well-publicized case of a farm operator being charged with illegal shooting of otter at the time the survey was conducted. As a result of the negative reputation that many salmon farm companies perceive the industry is obtaining, many respondents claimed that their sites operate under a policy of no guns permitted on the site.

4.4.7 Double bottom nets

Use and effectiveness: Of the 68 farms surveyed, 47 (69%) reported having double bottoms on their net pens. Over half of these users stated they used them against seal attacks; 34% rated them as highly or moderately effective (Figure 4-4A). Of the 13 farms that reported using double bottom nets against sea lions 54%, found them highly or moderately effective (Figure 4-4B).

Discussion: Netpens are now commonly equipped with a second layer of large-meshed netting on the bottom. Dogfish are the main predator for which double bottoms have been developed, but seals and sea lions also tend to attack from the bottom. Many operators felt that such attacks are directed primarily at "morts" that collect at the bottom, but once these are taken, predators' interests may turn to the live fish. Regular removal of morts is therefore a factor in diminishing bottom attacks and preventing potential predators from learning of the presence of live prey.

4.4.8 Underwater predator nets (bag and curtain nets)

Use and effectiveness: Just over half of the farms surveyed used underwater predator nets; 42.5% had bag nets and 9% had curtain nets. 38% of the respondents rated the effectiveness of bag nets against seal attacks and 13% indicated their use against sea lions. Almost all (88%) found them highly or moderately effective against these animals (Figure 4-4). Six farms used curtain nets; 5 of these used them in combination with double-bottom nets and rated this as effective against seals and sea lions.

Discussion: Two factors determine the effectiveness of underwater predator nets: the ability to create and maintain a gap between the predator and the netpen and the ability to resist damage or movement by predators. Predator nets are typically hung on the outside of walkways that run around sets of netpens, a distance of 0.5-1.5 m from the netpens. They are weighted at the bottom corners and sides to try to maintain this distance at all

depths. However, water currents tend to push the predator nets against the walls of the netpens, reducing the effective gap. Operators may try to counteract the effects of currents by adding more weights, but this in turn makes servicing the nets more difficult. Most operators who used these nets acknowledged that the gap between predator nets and netpens could not be maintained.

The resistance that the net presents to a predator depends on the gauge, weight and material of which the net is made, as well as the way in which it hangs in the water. A taut net is more difficult to bite through than a loose one; a heavily weighted net is more difficult to move than a lightly weighted one.

Other factors to consider are the costs of installing and maintaining these nets. Predator nets are a considerable capital cost, and given the effects of fouling, cleaning, moving and general wear and tear, they need replacement every few years. In addition, predator nets add substantial weight to pen systems, requiring that they be constructed more heavily than if predator nets were not installed. Considerable effort and expense is required to keep the nets free of fouling organisms. Fouled predator nets reduce water flow into the netpens and add to the stress on the pen structure. However, removing foulants requires that the nets be hauled up to allow washing and/or drying, or that they be scraped or vacuumed underwater. Predator nets are usually large so as to encompass a series of netpens, making hauling them to the surface difficult. Bag nets, which are attached under the netpens, are particularly difficult to service. It is also necessary to check the nets and repair any holes on a regular basis. This usually requires diving, but several operators pointed out that diving around such large nets is hazardous.

Many operators, therefore, felt the costs of underwater predator nets outweigh the benefits of reducing the risk of predator attacks. This is evidenced by the fact that despite being highly rated for their effectiveness against marine predators, only slightly more than half of the farms surveyed (51.5%) used underwater predator nets.

Although less commonly used, curtain nets have certain advantages over bag nets. Since they are not connected at the bottom to the entire predator net system, curtain nets are easier to pull up for cleaning or replacement than bag nets. This can be made still easier by arranging the curtain nets in discrete panels that can be individually hauled and replaced; each panel can be reattached to its neighbouring panels with large stitching or nylon rope ties. The major disadvantage of curtain nets is that they offer no protection from the bottom. However, the combination of a curtain net and double-bottom netpens gives the overall effect of a double mesh wall around the entire netpen system. The gap between the curtain net and netpen may be made to appear narrower by having the curtain net hang well below the netpen. None of the

five operators using this combination reported birds or animals getting in between the curtain net and netpen.

4.4.9 Other methods

One situation was reported where a hurricane lantern was installed on a rock outcrop used regularly as a sea lion haulout that was located within 0.5 km of a farm site. The sea lions apparently abandoned the site and have rarely been seen in the vicinity since.

4.5 Entanglement

Only 1 farm in this survey reported having a seal tangled in a predator net. In Scotland, however, entanglement of seals is a frequent occurrence. Ross (1988) cites 51% of sites surveyed reported entanglement, and estimates that a total of 113 seals are tangled per year at these sites. Extrapolating these figures to the 157 farms operating in Scotland, Ross estimates that total mortalities may be in the order of 1,050 seals. She notes, however, that the accuracy of figures received from farm operators varies greatly according to the level of net checking and management on the site, and whether operators may be underestimating (to prevent recrimination) or overestimating (to influence policies on predator control) their statistics.

Ross (1988) indicates that most operators regarded tangling as undesirable, either because it was considered to be inhumane or perceived to have adverse effects on fish husbandry. However, some operators considered tangling as a useful means of reducing a predator problem. In Scotland, predator nets are often made of light-gauge grey or black nylon with mesh sizes of 6-11 inches. The larger mesh size and lighter gauge are likely responsible for the greater entanglement reported in Scotland. In this survey of B.C. salmon farms, mesh sizes of predator nets ranged from 2-5" and a heavier gauge of nylon was used (see chapter 7).

4.6 Summary

* Problems were encountered with seals at 62% of the farm sites surveyed (n=68). Predation was the most common problem (40%); stress (17%) and damage to equipment (19%) were also cited. Just over 25% of the farms surveyed reported losing fish to predation or stress caused by seals in the past year, the collective total loss being 55,000 - 60,000 fish.

* Sea lions were considered a problem by 22% of the farms surveyed. Fish loss due to predation, stress and equipment damage by sea lions was reported by 7% of the farms.

* Dogs, shooting to scare, double bottom nets and bag nets were cited most frequently as methods used to prevent predation by seals and sea lions. Bag nets received the highest effectiveness rating against these animals, followed by double bottom nets and shooting to scare. Although not extensively used, underwater acoustics, seal bombs and curtain nets were rated as being effective by more than 50% of those would did use them.

5. FURBEARERS: RIVER OTTER AND MINK

5.1 Background: Distribution and Feeding Habits

5.1.1 River otter

The river otter (*Lutra canadensis*) is an abundant species along waterways and throughout B.C.'s coast and offshore islands. Otters range from 0.9-1.3 m in length and 5-13 kg in weight. The social unit consists of an adult female and her offspring, while males generally are solitary (Melquist and Hornocker, 1983). They move within home ranges, although their boundaries frequently overlap and change according to food availability (Hornocker *et al.*, 1983).

On the coast, otters' preferred habitats typically have a freshwater pond or stream associated with them (McTaggart Cowan and Guiget, 1978). They are opportunistic feeders, taking prey in proportion to their availability. In coastal environs, their main prey are fish that are abundant, midsize (15-35 cm), easy to catch (sluggish or easily fatigued) and close to shore (Stenson *et al.*, 1984). Common prey species are surfperch, sculpin, flounder, rockfish and greenling. Salmonids are not regular items in their diet, but they will feed on salmon when readily available; for example, otters will concentrate along salmon spawning rivers in autumn (Hornocker *et al.*, 1983). Otters are primarily nocturnal in their feeding habits, but become more diurnal during the winter (Melquist and Hornocker, 1983).

5.1.2 Mink

Mink (*Mustela vison*) are abundant in B.C.'s marine and freshwater environments. They are considerably smaller than otters; adult males are 0.5-0.7 m in length and weigh from 0.7-1.6 kg. They too are opportunistic feeders. Rabbits and rodents are dominant prey species, but in coastal environments, over 50% of their diet may consist of fish found in shallow waters and tide pools and crustaceans (Dunstone and Birks, 1987). Fish prey are particularly important in winter when terrestrial prey are scarce; females may prey more heavily on fish than males because many terrestrial prey species are too large for them to catch (*ibid.*).

5.2 Frequency of Occurrence Around Salmon Farms

River otter were the second most frequently observed mammal next to seals (Figure 5-1A). Regular or frequent sightings were reported by 25-50% of respondents with the greatest frequency in spring. Of the 61 farms that observed otter, only 5 reported an increase and 4 reported a decrease in numbers. Most of the decreased frequencies were attributed to trapping or shooting to get rid of problem animals.

In most cases, mink were observed only occasionally (Figure 5-1B). Of the 30 farms that observed mink, 1 reported an increase and 4 reported a decrease in their occurrence.

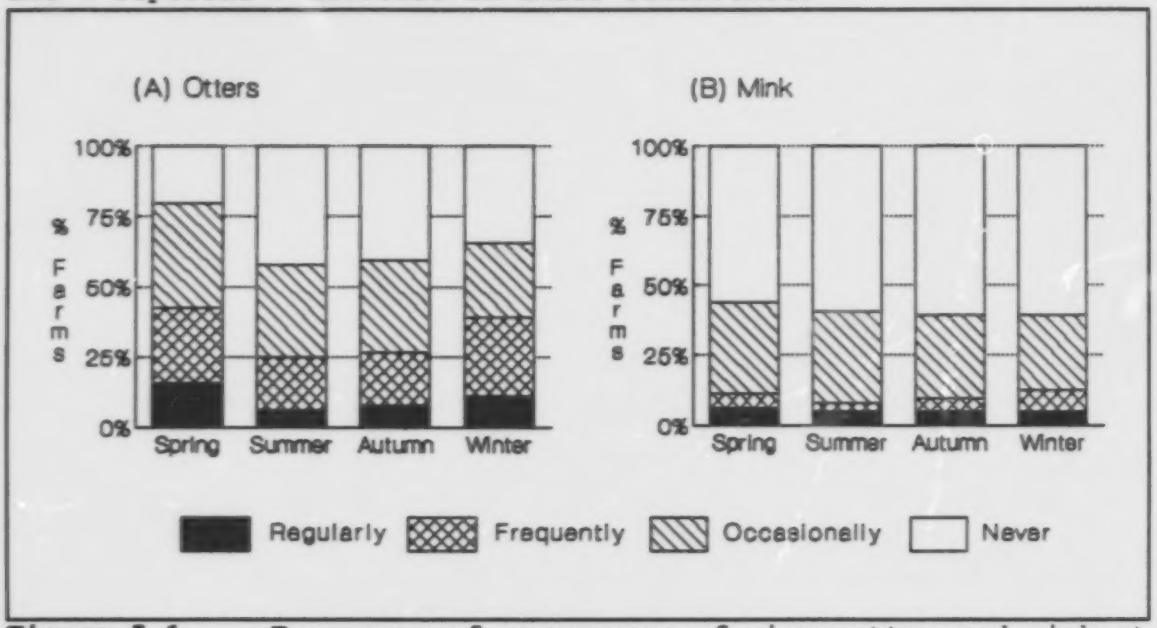

Figure 5-1: Frequency of occurrence of river otter and mink at farm sites surveyed. (n=68)

5.3 Problems Reported by Salmon Farms

5.3.1 Predation and stress

Otter: River otters were cited most frequently of all the wildlife groups as posing predation problems. Almost half of the respondents reported predation by otters and of these over half cited it as a severe problem (Figure 5-2A). Twenty-one (31%) of the farms surveyed reported a total of 30,600 fish lost to predation or stress by river otter (Figure 5-3). Most attacks occurred between dusk and dawn, and most fish taken were 300g - 2kg in size. A few operators reported that otters chewed holes through predator nets to get at fish. More commonly, the animals jumped or climbed into netpens from walkways, escaping by climbing back up the sides of the netpen. Top nets were a deterrent but only if securely fastened to the netpens. Several operators complained that otters do not just take a few fish but go into an attack frenzy, leaving many fish seriously wounded. The persistence of otter predation problems was variable. Some operators reported that otters were around a few times but lost interest, while others claimed an ongoing battle with animals that exhibit increasing boldness and cunning.

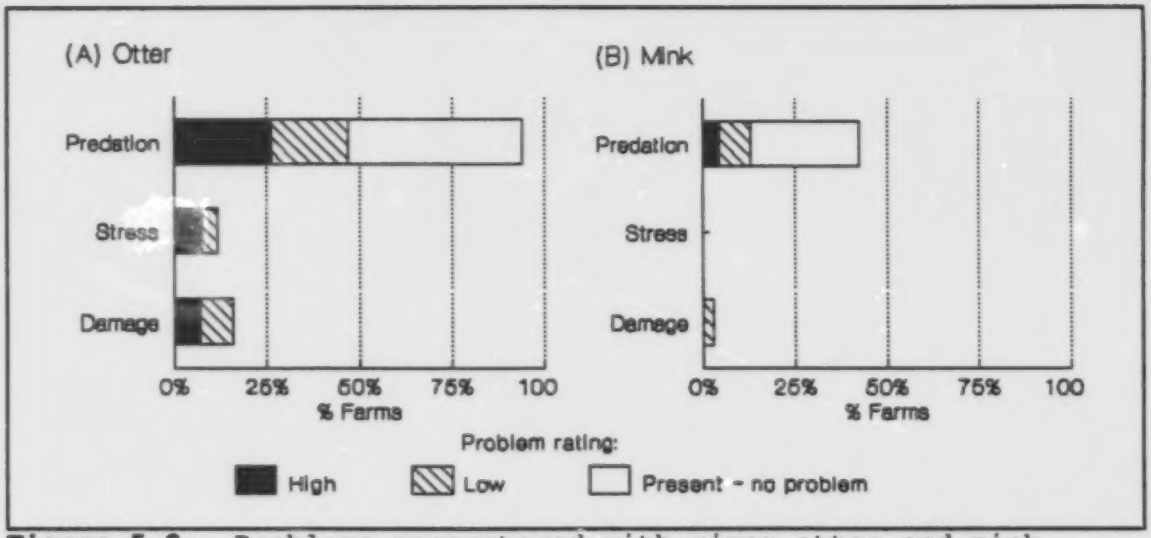

Figure 5-2: Problems encountered with river otter and mink (n=68)

Mink: Only 18% of respondents reported predation by mink and only 3 farms (4.3%) considered it to be a severe problem (Figure 5-2B). Four farms experienced losses to mink totaling 3800 fish (Figure 5-3), mostly of fish less than 500g.

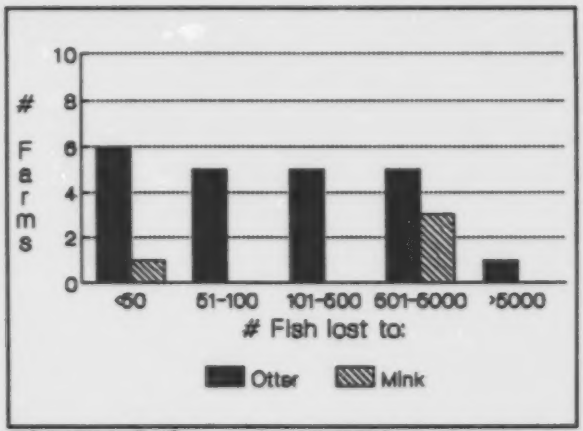

Figure 5-3: Direct fish losses to river otter and mink

Several operators were unsure whether predation losses were attributable to mink or otter. Otters typically fed on larger fish than mink, but the size ranges overlapped. Otters also characteristically ate the heads and organs of fish, leaving the carcass behind. Scat on the walkways was another common sign used to indicate the presence of these animals, with otter scat usually being larger than mink.

By comparison, problems with otter predation were reported by only 16% of 51 farms surveyed in Scotland (Ross, 1988). This may be due to the considerably lower otter populations in Scotland, although otter were regularly seen at 78% of the Scottish salmon farms surveyed. Both otter and mink predation have been reported as problems at freshwater hatcheries and rearing facilities, with the latter predator being more regularly cited. For example, in

a survey of 287 hatcheries in the eastern U.S., the most frequently reported mammalian predators were raccoons, man and mink (Parkhurst *et al.*, 1987).

5.3.2 Damage to equipment and consequent fish loss

Eleven farms attributed damage to underwater predator and top nets to river otter and 3 to mink (Figure 5-2). One respondent claimed costs in thousands of dollars to hire a diver on an ongoing basis to repair underwater holes chewed by otters in bag nets. Only one farm reported losing fish because of damage caused by wildlife, where 25,000 smolts escaped through small holes created just below the surface of a netpen; the respondent suspected otter but noted that mink could also be the cause.

5.4 Methods Used to Deal with Problems

5.4.1 Dogs

Use and effectiveness: Of the 35 respondents who reported using dogs against river otter, 14 (40%) found them to be highly or moderately effective and 18 (51%) found them of little or no effect (Figure 5-4). Seven respondents used dogs against mink, of which 5 found them to be of high or medium effectiveness.

Discussion: Dogs were fairly effective against mink because these animals are small and largely land-based. Otter on the other hand have superior swimming and diving abilities, and consistently teased dogs by staying just beyond their reach.

5.4.2 Night Watchman

Use and effectiveness: Twelve (18%) respondents reported using night watchmen to prevent river otter attacks (Figure 5-4); nine found them highly or moderately effective in reducing the presence of these animals. Only 2 respondents cited using watchmen for mink; 1 rated it as moderately successful and the other said it had no effect.

Discussion: According to survey respondents, more river otter attacks occur between dusk and dawn than in daylight hours, making the use of night watchmen worth considering. The major determining factor in the effectiveness of this measure is the vigilance of the watchman.

5.4.3 Shooting

Use and effectiveness: Twenty-three (34%) respondents used guns to scare off river otter; 10 (43%) of these found it highly

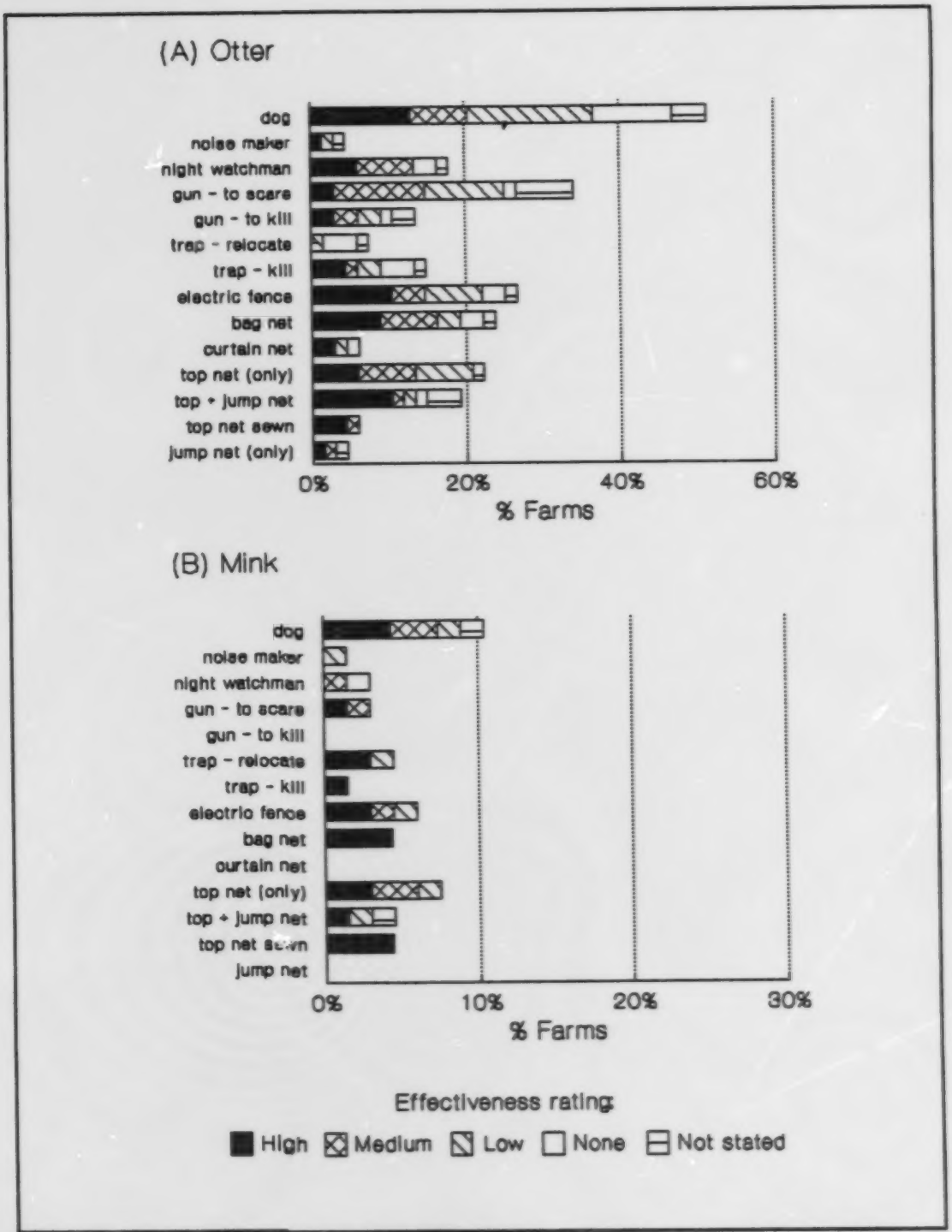

Figure 5-4: Use and effectiveness of predator prevention methods against river otter and mink (n=68)

or moderately effective in getting rid of problem animals. Nine (13%) reported shooting to kill river otter of which 4 found it to be highly or moderately effective (Figure 5-4). Only 2 respondents reported shooting to scare mink; both rated it as effective.

Discussion: Furbearers are protected under the B.C. *Wildlife Act*, which has provisions for hunting or trapping wildlife without a permit or licence for the purpose of protecting property when certain circumstances are met. However, the provision applies only to wildlife that are a menace to domestic animals or birds, which does not include finfish or shellfish (Caldwell, 1987). The Wildlife Branch can issue permits under other provisions of the Act to allow fish farmers to destroy problem wildlife, and has done so when it is apparent that other preventive measures have failed. Penalties for offenses under this Act range from $100.00 to $5000.00.

As mentioned in the previous chapter, the figures obtained in this survey probably underestimate the use of guns on salmon farms, as there is some reluctance to divulge this type of information. It is not known if the respondents had permits to destroy problem otter.

5.4.4 Trapping

Use and effectiveness: Sixteen (23.5%) of the farms surveyed used trapping as a predator control method. Eight farms set traps or called in trappers with the intention of relocating problem animals; 11 farms (3 of which also cited using traps to relocate) used this method to kill the animal. River otter were the major object although 2 farms used traps specifically for mink (Figure 5-4). No one rated trapping to relocate as effective against otter, though 2 found it eliminated problems with mink. Trapping to kill was rated effective by 4 of the 10 operators that used it against otter; only 1 respondent trapped specifically to kill mink and rated it as highly effective.

Discussion: Trapping is rarely a long-term solution to a predator problem because "it fails to address why the animal was attracted to the site in the first place, and does not discourage others of the same species from causing additional problems in the future" (B.C. Ministry of Agriculture and Fisheries, 1987:3). In this survey, trapping appeared to be effective when a specific, persistent animal was removed and no others moved into its range. The respondents who rated trapping as of low or no effect were either unsuccessful in catching the problem predator or had other animals move in to replace the removed animal.

In general, it appears that mink were more easily trapped than otter. However, the fact that several operators who thought that they had a problem with otter caught only mink suggests that in

some cases, problems that are blamed on otter may actually be due to mink.

Trapping may legally be done only under the authority of a valid trapping licence or with a permit issued under the B.C. *Wildlife Act*. A farm operator can apply to the Ministry of Environment and Parks for such a permit in order to remove problem animals. Alternatively, an operator can ask a trapper who is licensed for that area to assist in removing problem animals during the open trapping season (B.C. Ministry of Agriculture and Fisheries, 1987).

5.4.5 Electric fence

Use and effectiveness: Electric fences were used by 18 (27%) of the farms surveyed. In all cases, the fences were installed to prevent predation by river otter, with mink also cited by a few farms. Ten of the 18 farms found electric fences to be highly or moderately effective against otter while 7 found fences to have little or no effect on otter predation activity (Figure 5-4).

Discussion: Electric fences consisted of an electrified wire of the type used in pig or chicken pens, with power provided by the local electrical system or by a car or boat battery. On some sites, the wire was attached to the outside of the walkways (Plate 5-1) where it would shock any animal that attempts to climb out of the water onto the walkway. This configuration is most effective in combination with underwater predator nets hung from the outside of the walkway, which would force the otter to get onto the walkway from the outside in order to gain access to the netpens. The fact that the animal would be wet with saltwater at the time of contact would enhance the shock effect.

At 2 sites, the wire was attached to the log floats beneath the walkway where it would brush an animal trying to climb over the log when approaching a netpen. At other sites, the wire was attached to the stanchions that supported the net pens, running around the net pens themselves rather than the walkway (Plate 5-1). In this configuration, it would touch an animal that tried to climb onto the walkway from the inside or attempted to jump into the netpen from the walkway. Another variation was the use of "rabbit fencing", which consisted of an electrified mesh (8x8 cm) about 75 cm high installed around the outside of the walkway (Plate 5-2).

Most of the farms that rated electric fences effective used a combination of one line running around the outside of the walkways (combined with underwater predator nets) and a second line around the stanchions supporting the netpens. The "rabbit" fence was rated as highly effective at the one site where it was used. Users felt that if installed and maintained appropriately, electric fences have the advantage of deterring the animals without long

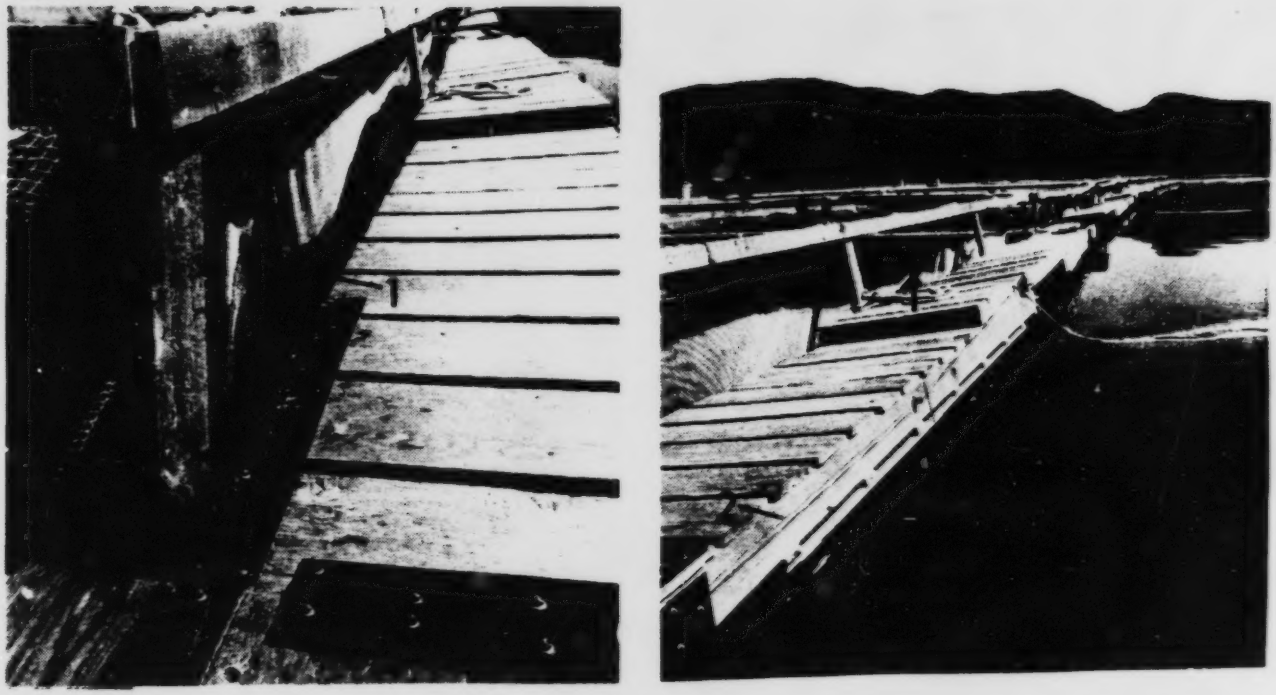

Plate 5-1: Electric fence around a salmon farm: lines around netpens (1) and walkways (2).

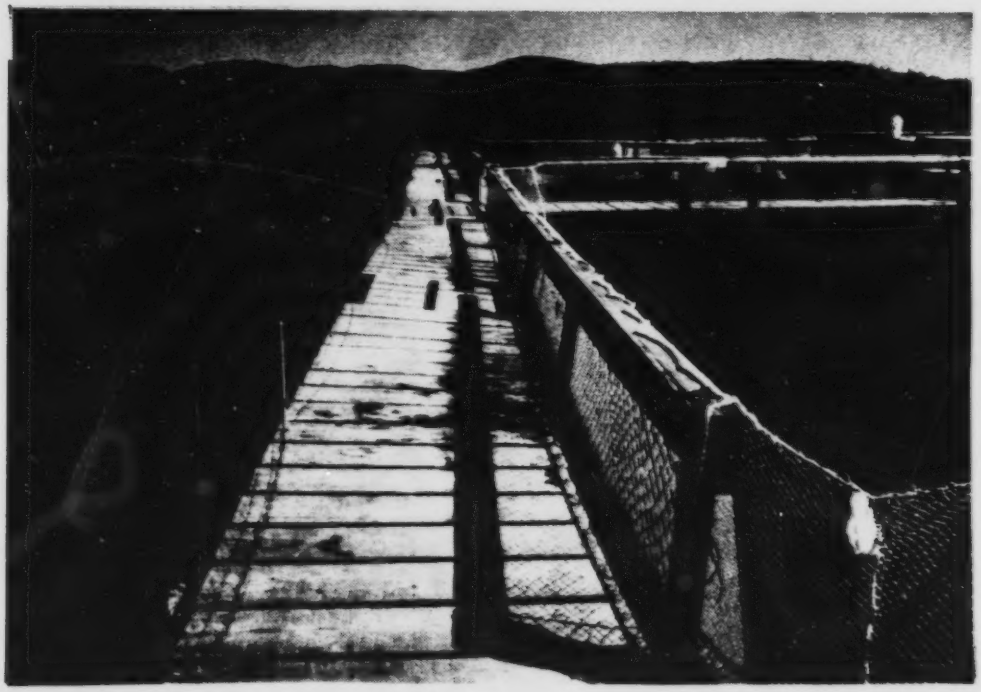

Plate 5-2: "Rabbit" electric fence on salmon farm.

term harm to them. They emphasized the importance of this method as a "training" device; if it is installed at the start of operation, otter are discouraged before they learn predatory behaviour patterns. Several operators found that after running it initially, they could leave the system off for several months at a time, turning it back on to deter any renewed curiousity by otters.

Costs of an electric fence system were not prohibitive. One operator cited a cost of $100.00 for a generator, $100 for a battery and $40-100 for wire and insulators, depending on how many netpens are being encircled. A standard boat or car battery required recharging about once a week. The "rabbit fencing" system was more expensive, costing about $600.00 to encircle eight 40'x40' netpens.

To be effective, electric fence systems must be installed so as to encompass all netpens and minimize gaps in the electrical field at such places as entrances to walkways or docks. Regular maintenance and repair are also necessary; a break or shorting at any spot in the fence, in most cases, renders the entire fence ineffective. A major advantage of the mesh "rabbit fence" is that it is grounded such that if one horizontal wire is damaged, the remaining wires retain current and the rest of the fence is still functional.

Respondents who rated electric fences as having low or no effectiveness, or who considered using them in the past but rejected the idea, felt that they got in the way or easily broke during routine activities such as net cleaning or installation. Others felt that electric fences were too difficult to maintain at sites that are subject to rough weather or strong currents because movement in the walkways and pens broke the lines or the splashing of seawater caused short circuits. Several operators felt fences posed a hazard to staff if they forgot to turn the system off before diving or doing other wet work. One operator commented that electric fences are virtually impossible to use on steel pen systems because of the tendency for the wires to touch the metal in rough weather and short circuit. It is noteworthy that all the farms visited that had electric fences had wooden walkways and stanchions.

5.4.6 Underwater predator nets

Use and effectiveness: Sixteen (23.5%) respondents reported using bag nets to deter river otter, 11 of which rated them as highly or moderately effective (Figure 5-4). Four (6%) reported using curtain nets of which 3 rated them as highly or moderately effective. Only 3 farms reported using bag nets to deter mink and all rated it as highly effective.

Discussion: Underwater predator nets are not as important a deterrent against otter and mink as they are against marine mammals. However, to enhance their effectiveness against furbearers, operators should ensure that the mesh size is sufficiently small to keep mink from swimming through. The nets should be attached to the walkway or floatation structure so that there are no gaps that would allow an otter or mink to climb through.

5.4.7 Top nets

Use and effectiveness: A total of 57 farms (84%) used some type of top net. Three configurations were identified in the course of the survey (Figure 5-5):

i) simply hooking the net to the top rail bordering the walkway and netpens. The net is suspended by pulling it taut over the hooks.

ii) hooking the net to the top rail but also attaching it with large stitching or ties to the top of the net pen.

iii) combining a top net with a jump net which extends from the top rail to the walkway.

Thirty-four of the 57 farms reported using top nets against river otter predation and 11 against mink (Figure 5-4). Simple hooked top nets were used by 17 of these respondents, 13 used top nets with a jump net, and 4 had top nets sewn down to netpens. Although less frequently used, top nets that were sewn down to netpens were rated effective by a higher percentage of their users than the other two types.

Discussion: Top nets are typically made of large-meshed (1-6" stretch) netting suspended horizontally over net pens. As well as keeping out avian predators, top nets are used to prevent furbearers from jumping or climbing over the walls and into the netpens. Each of the 3 types of top nets configurations has advantages and disadvantages. A top net that is simply hooked to uprights can be easily let down or removed for accessing the net pen, but it leaves a gap between the top net and net pen that may be sufficient to let an otter or mink crawl through. Sewing or tying the top net to the net pen seals this gap but the sewing or ties must be undone whenever the pens need to be accessed for cleaning, diving for dead fish, etc. Adding a jump net provides an extra net barrier between the walkway and the net pen and does not get in the way of pen maintenance.

Size and weight of the mesh may be factors in the effectiveness of top nets against these animals. Some operators claim that both mink and otter have chewed holes in top nets. This might be prevented by using heavier gauge or smaller mesh netting.

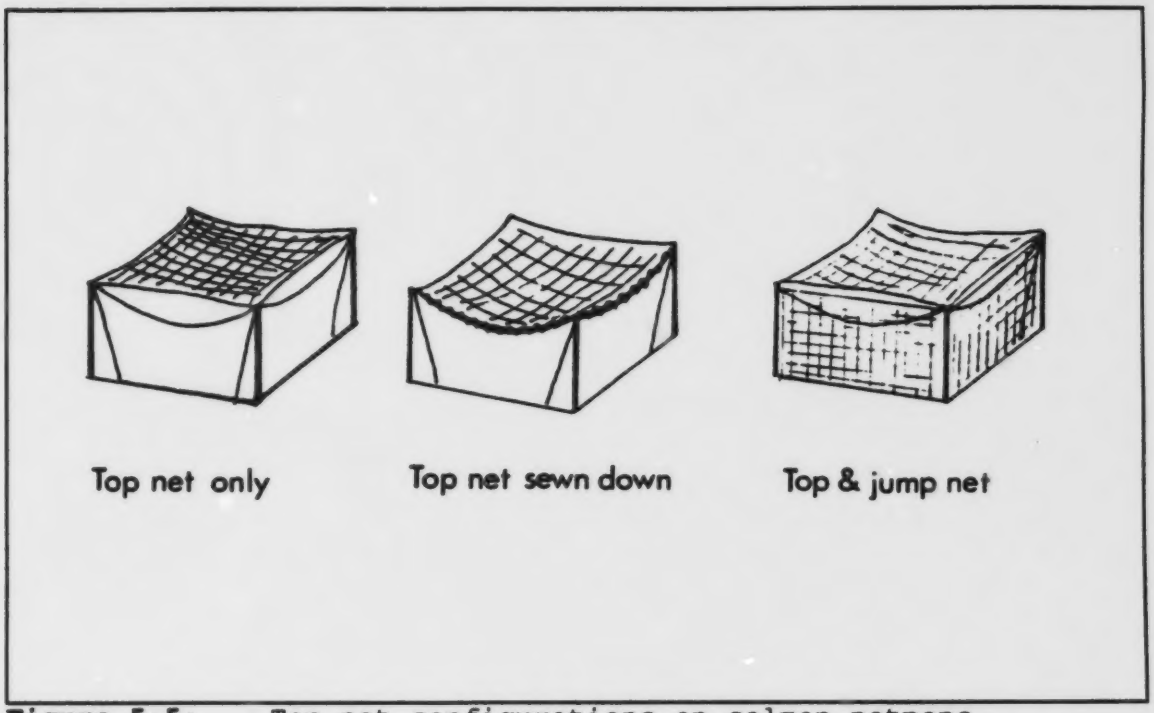

Figure 5-5: Top net configurations on salmon netpens.

5.5 Summary

* River otter were considered a problem by 63% of the sites surveyed (n=68). Predation was the most common problem (49%); stress (16%) and damage to equipment (18%) were also cited. Of the farms surveyed, 31% reported losing fish to predation or stress caused by otter in the past year, the collective total loss being approximately 30,600 fish.

* Mink were considered a problem by 16% of the farms surveyed, with predation being cited in almost all cases. Fish loss due to mink predation was reported by 6% of the farms for a collective loss of 3800 fish.

* Dogs, shooting to scare, top nets and electric fences were cited most frequently as methods used to prevent predation by otter and mink. When comparing ratings for each method, top nets sewn to netpens were rated effective by the highest proportion of its users, followed by other types of top nets, bag nets and electric fences.

6. AERIAL BIRDS

6.1 Distribution and Feeding Habits

The main species of interest in this survey are: Great Blue Heron, Belted Kingfisher, Bald Eagle, and gulls. Osprey and crows were also noted occasionally and are mentioned where applicable.

6.1.1 Great Blue Heron

Great Blue Herons (*Ardea herodias*) are found throughout the B.C. coastal area. Normally solitary, these birds congregate in colonies during the breeding season (March - July). There are 84 known colony sites along the coast, the majority of which are found along SE Vancouver Island, the southern Gulf Islands and the Fraser lowlands (Campbell *et al.*, 1989). Herons build their nests in trees; up to 40 nests may be situated in a single tree in a colony (*ibid.*).

Great Blue Herons are most numerous on the coast during the summer months when foraging aggregations from nearby colonies may approach 300 individuals (*ibid.*). In coastal environments, they favour eelgrass beds and tidal marshes where they feed on shallow-water fish (sculpins, stickleback, shiner perch, flounder, salmon fry), crustaceans (ghost and mud shrimp), and marine worms (Verbeek and Butler, 1989). They feed from a standing position, capturing their prey with a swift plunge of the head and long beak.

6.1.2 Belted Kingfisher

The Belted Kingfisher (*Megaceryle alcyon*) both breeds and winters throughout coastal B.C. (Godfrey, 1979). These birds feed primarily on small fish, capturing their prey by diving from the air or a perch. They favour elevated perching places such as trees, posts or wires that overhang water bodies from which they can search for their prey.

6.1.3 Bald Eagle

The Bald Eagle (*Haliaeetuss leucocephalus*) is found year-round throughout the B.C. coast. Nests are built high in large trees and are usually solitary. Bald Eagles feed on carrion as well as catching fish, birds and small mammals. Rockfish and ling cod are common prey species as are gulls and sea birds in some areas (Verbeek and Butler, 1989). Eagles frequent salmon streams during spawning season.

6.1.4 Gulls

Glaucous-winged Gulls (*Larus glaucescens*) occur year-round, both breeding and wintering along the B.C. coast. They are opportunistic feeders, foraging on refuse around towns and cities

and on fish and marine invertebrates in less populated areas (Vermeer and Ydenberg, 1989). Herring Gulls (*L. argentatus*) winter on the B.C. coast; they are primarily scavengers, gathering around fishing vessels, fish plants and dumps to feed on scraps and refuse (Godfrey, 1979). Bonaparte's Gulls (*L. philadelphia*) breed in northern interior areas of western Canada and Alaska and winter along the southern B.C. and U.S. coast. They are most abundant along the B.C. coast during spring and fall migrations. Their main prey are euphausiids (in upwellings), amphipods and small fish (herring and sandlance; Vermeer and Ydenberg, 1989); migrating flocks are particularly numerous around herring spawning areas in spring.

Campbell *et al.* (1989) note differences in the feeding behaviour of Bonaparte's and Glaucous-winged gulls preying on salmonid fry released from a hatchery:

> "The migratory Bonaparte's gulls occurred in tight feeding aggregations with peak numbers corresponding closely to fish density, while the resident Glaucous-winged Gull was distributed in loose flocks and their numbers did not seem to bear any direct relationship to numbers of fishes.... In 1980, 8 species of piscivorous birds captured an estimated 300,000-354,000 chinook fry which ranged between 10.4 to 12.2% of the total release (from the hatchery). The most efficient predator was the Bonaparte's Gull which accounted for 8.3 to 9.9% of that release."

6.2 Frequency of Occurrence Around Salmon Farms Surveyed

Herons and kingfishers were observed regularly or frequently by over 50% of the respondents over all seasons (Figure 6-1A,B). Of the four species/groups, Bald Eagles were observed by the greatest number of farms but gulls were seen on a regular basis by the highest percentage of farms (Figure 6-1C,D). There were few differences in the frequency of occurrence from season to season. The Great Blue Heron was the only species that displayed a regional difference, occurring with the greatest frequency at farms in the southern Vancouver Island area which reflects the concentration of heron colonies located in this region.

6.3 Problems Reported by Salmon Farms Surveyed

6.3.1 Predation

Great Blue Heron: Predation problems were cited by 51% of respondents, but only 6 (8.6%) considered it to be a serious problem (Figure 6-2). Many respondents felt that herons' attempts to prey on penned stock are largely unsuccessful, or that the

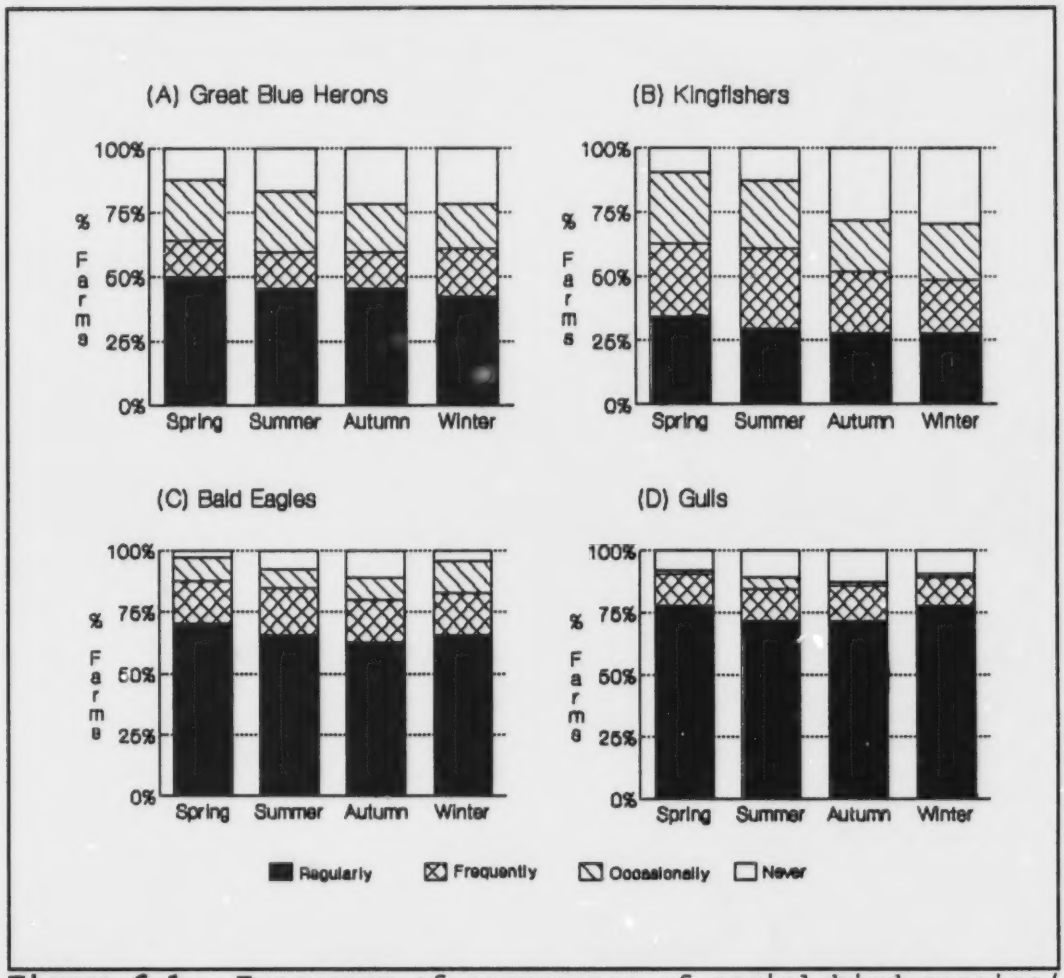

Figure 6-1: Frequency of occurrence of aerial bird species/ groups at sites surveyed (n=68)

birds were feeding primarily on the pile perch and "shiners" attracted to netpens by excess fish food. Sixteen farms (23.5%) reported a collective loss of approximately 4200 fish to herons in the last year; half of these cases involved losses of less than 50 fish (Figure 6-3). The majority of fish preyed on were smolts of less than 300 g; losses of larger fish were caused by wounds inflicted by the birds rather than actual takes.

Herons feed on farm stock in a variety of ways. They commonly stand on walkways or floats and strike at fish through net pens. Strike marks on larger fish were fairly common (Figure 6-4). There were also reports of herons standing in the middle of a top net, thereby sinking it to the surface of the water and allowing them to feed on the fish below. This strategy is particularly successful if the top net is not taut or is suspended too close (<1

m) to the surface of the water (Ross, 1988). A few operators had observed herons banding together to collectively weigh down a top net. There was one observation of a heron swooping down over a netpen and catching a smolt, but such incidences are rare given the limited open space of most net pens and the presence of top nets at the majority of sites.

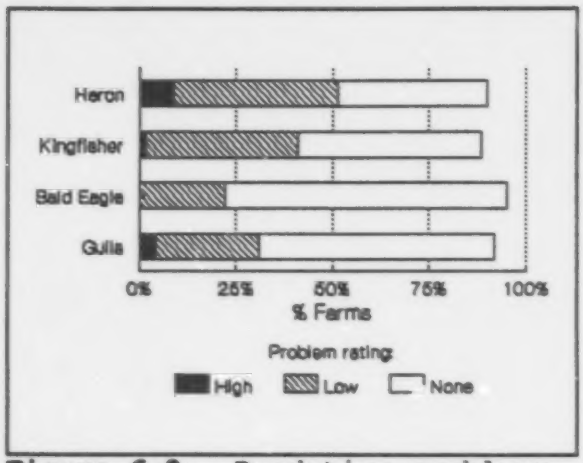

Figure 6-2: Predation problems with aerial birds at sites surveyed (n=68)

By comparison, 63% of farm operators that were interviewed in Scotland regarded heron predation as a problem; actual losses or damage were reported by 29% of the farms covered by questionnaire (Ross, 1988). Heron predation is also a common problem in freshwater hatcheries (Parkhust *et al.*, 1987).

Belted Kingfisher: As with herons, predation by kingfishers was reported by a relatively high proportion of respondents (42.8%) but the majority considered it not to be a serious problem (Figure 6-2). Eleven farms (16%) reported losses totalling about 2200 fish, all smolts less than 300 g (Figure 6-3). Such losses usually occurred on unprotected net pens. Kingfishers are cited as common predators around freshwater facilities (*ibid.*).

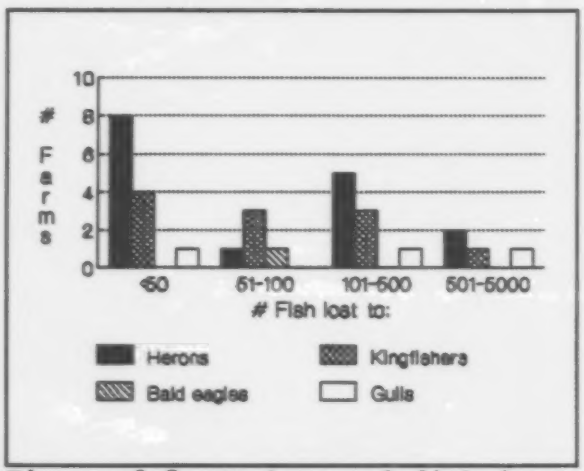

Figure 6-3: Numbers of fish lost to aerial birds at sites surveyed

Bald Eagle: Predation by eagles was reported by 21.4% of respondents but all cited it as not serious (Figure 6-2). The only loss of any proportion was at one farm where eagles took about 100 fish over the course of a year. Eagles were very common around the farms but operators felt that most attempts to prey on the caged fish were unsuccessful due to the limited space that net pens allow for swooping down and taking off. The few fish that eagles take are typically sick and swimming slowly at the surface.

Gulls: Predation by gulls was cited as a problem by 30% of the respondents, a serious one at 3 farms (4.4%; Figure 6-2). Of these

3 cases, two involved migrating flocks of Bonaparte's Gulls feeding on smolts released into cages in the spring. Together, these farms lost about 850 smolts to gulls over the past year (Figure 6-3). All 3 farms did not have top nets over their smolt pens; installation of top nets was planned to remedy the problem.

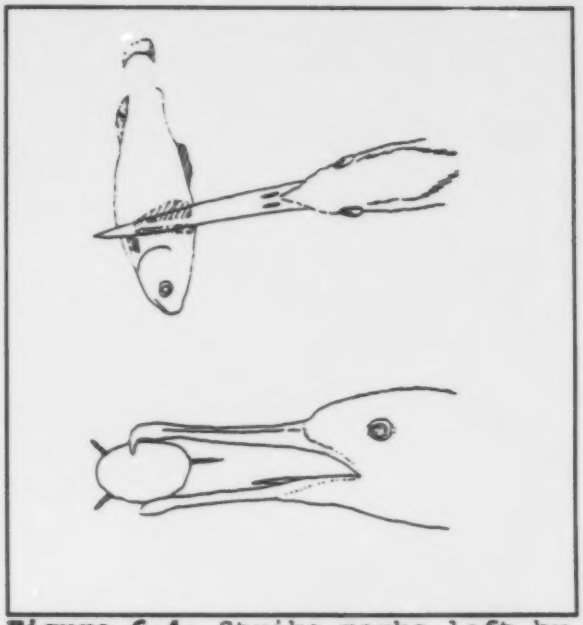

Figure 6-4: Strike marks left by (a) herons and (b) cormorants. Shaded areas indicate scale loss (from: Beveridge, 1987).

6.3.2 Entanglement

Entanglement of herons was reported by 12.8% of respondents (Figure 6-5). Herons became entangled in underwater predator nets when attempting to perch on to the top of them, or when falling off walkways or floats in between predator nets and netpens. They also occasionally became enmeshed in top nets when walking over them. Entanglement of kingfishers was cited by 10% of the respondents (Figure 6-5). Kingfishers dive with their wings tight to their sides but must flap their wings to fly away. They were typically tangled in or trapped under top nets that were made of mesh that was large enough to allow them to dive through but that prevented them from flying out. The birds were usually rescued and released.

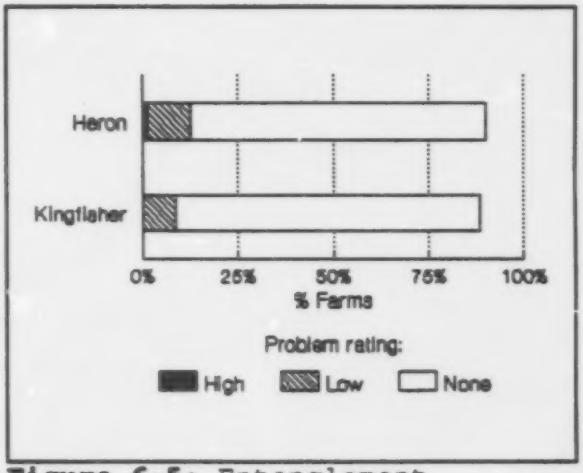

Figure 6-5: Entanglement problems with aerial birds at sites surveyed (n=68)

Entanglement of aerial predators appears to be a frequent occurrence in Scotland. Ross (1988) estimates that total mortalities may be in the order of 200 herons per year at the 157 farms in Scotland. She notes that the accuracy of figures received from farm operators varies according to the level of net checking and management on the site, and whether operators may be underestimating (to prevent recrimination) or overestimating (to influence policies on predator control) their statistics.

6.3.3 Other problems

Gulls (primarily glaucous-winged) and crows were reported getting into bags of fish feed. A few operators felt that birds flying over or landing on the surface of the net pens stressed the fish, but none of them considered the problem serious.

6.4 Methods Used to Deal with Problems (Figure 6-6)

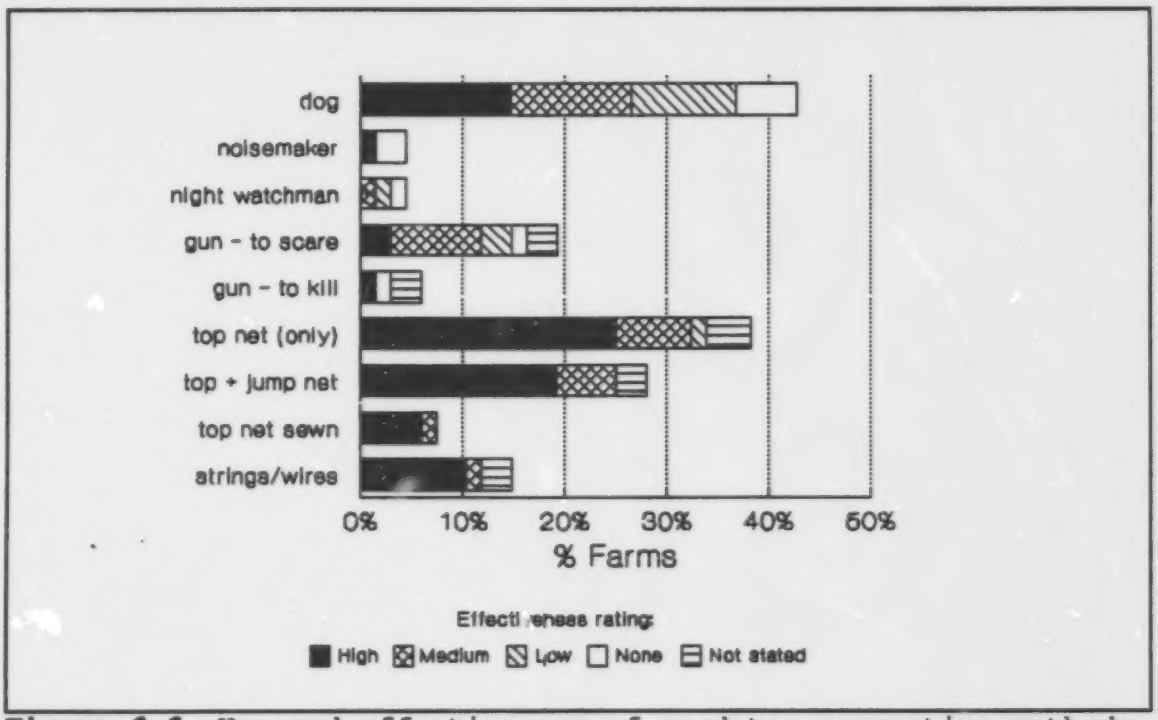

Figure 6-6: Use and effectiveness of predator prevention methods against aerial birds (n=68)

6.4.1 Harassment methods

Dogs were used by 29 (43%) respondents to scare birds away, 18 of whom found them to be highly or moderately effective. Three farms used noisemakers; only 1 rated it as effective. Similarly, 3 farms cited night watchmen, with effectiveness ratings of moderate to no effect. Thirteen respondents (19%) cited the use of guns to scare birds away, 8 of which found them highly or moderately effective.

6.4.2 Removal methods

Shooting to kill aerial birds was acknowledged by 4 farms. Only 1 rated shooting to kill as effective; a rating was not indicated in the other 3 cases. The users also did not indicate which species were being targetted.

The federal *Migratory Birds Convention Act* protects coastal migratory bird species from killing and harassment. Permits can be obtained under this Act from the Canadian Wildlife Service or the B.C. Wildlife Branch to use firearms to scare and kill problem birds. In B.C., the policy is "to issue scare permits relatively liberally, but only to issue kill permits after it has been established that both scare methods and predator nets are ineffective" (Caldwell, 1987:33). Penalties for contravening the Act range from $10.00 to $300.00; these penalites are under review (*ibid.*).

6.4.3 Exclusion methods

Top nets of some configuration were used against birds at 50 (74%) of the farms surveyed. Top nets alone were used at 26 (38%) farms, of which 22 (85%) rated them highly or moderately effective in eliminating problems with aerial predators. Top nets with jump nets were used by 19 (28%) respondents, 17 (89%) of which rated them highly or moderately effective. Top nets that were sewn down to net pens were used at 5 (7%) farms, all of which rated them to be highly effective. Overhead strings or wires were used at 9 (13%) farms and were rated effective by 7 of them. Two sites had installed tarpaulin covers to provide shade over smolt pens, and found them incidentally useful against bird predation.

Besides excluding birds from the air, a few farms took extra measures to prevent herons from preying from walkways. In addition to jump nets, low boards around the net pen frames can prevent herons from attempting to spear fish through the netpen mesh. One farm also created a greater distance between the netpen and the walkway by "waisting" the netpen - cinching it in slightly at the water's surface - so as to discourage heron predation from walkways and floats.

Top nets or screens and overhead wires are commonly used at freshwater hatcheries and rearing facilities, along with perimeter fences (Meyer, 1981; Martin, 1982; Parkhurst *et al.*, 1987; Beveridge, 1987). In the case of overhead strings or wires, a spacing of 30-50 cm was found to be effective in excluding most gulls and birds of prey (Quebec Dept. of Recreation, 1987).

6.5 Summary

* Of the aerial birds, Great Blue Herons caused the highest frequency of problems around the farms surveyed. Predation by herons was reported by 51% of the respondents (n=68), but only 8.6% considered it to be a serious problem. 23.5% of the farms reported losses to herons totalling about 4200 fish over the previous year, most of which were smolts.

* Predation by Belted Kingfishers was reported by 43% of respondents, but only 2% rated it as a serious problem. 16% reported losses totalling some 2200 smolts over the previous year. Gull predation was cited by 30% of respondents and rated as a serious problem by 4.4%; a collective loss of 850 smolts over the last year was reported. The absence of top nets was a common trait among farms that experienced these predation problems with gulls and kingfishers.

* Predation by eagles was reported by 21.4% of respondents but all rated it as minor.

* Top nets were the most frequently cited and most highly rated method for preventing predation by aerial predators. Overhead strings or wires were also used with considerable effectiveness. Dogs and shooting were also used but were rated effective by fewer respondents.

* Entanglement of kingfishers and herons was reported by 10 and 12.8% of the farms surveyed respectively. The majority involved top nets or predator nets and most resulted in capture and release of the birds.

7. DIVING AND DABBLING BIRDS

7.1 Distribution and Feeding Habits

The main bird groups of interest to this survey are cormorants, grebes, loons, diving ducks, dabblers and alcids. In general, most of the species are found in greatest abundance on the coast in winter and during spring and fall migrations; only 2 species of cormorants and 2 alcids breed along the coast in areas overlapping salmon farms (Table 7-1). Cormorants, grebes, and loons feed primarily on small fish; herring form a major percentage of their diet. Of the diving ducks (Table 7-1), mergansers are the only species that feed almost exclusively on small fish. Barrow's and Common Goldeneye and Bufflehead, often referred to as "bay" ducks because they occur predominantly in bays and sheltered waters, feed mostly on subtidal invertebrates; mussels, snails, and herring eggs (Vermeer and Ydenberg, 1989). The "sea" ducks (Scoter sp., Oldsquaw and Harlequin ducks) occur in more open waters and feed predominantly on bivalves, but also snails, herring eggs and crabs (*ibid.*). Alcids feed on small fish and large zooplankton. Dabblers feed on marine plants and herring eggs.

7.2 Frequency of Occurrence Around Salmon Farms

Of these bird groups, diving ducks had the highest frequency of occurrence year-round among the farms surveyed (Figure 7-1). Most diving bird groups occurred more frequently in winter and spring. Farms in the southern Vancouver Island region had the highest percentage of respondents (n=7) reporting diving birds around their farms. In the other 3 regions, cormorants, grebes/loons and diving ducks were observed by at least 50% of the respondents. Dabblers were generally infrequently seen around the farms.

While some of the birds may have been interested in the farm fish, many appeared to be attracted to the small fish that concentrate around salmon farm netpens feeding on the excess fish food. Other species (e.g., Scoters) fed on mussels growing on nets and other farm structures, an activity which farm operators regarded as beneficial in that it reduced fouling.

7.3 Problems Reported by Salmon Farms Surveyed

7.3.1 Predation

Of the diving birds, cormorants were cited most frequently as attempting to prey on farm fish; 12 farms (17%) reported predation problems with these birds, 2 rated it as severe. The frequencies of predation problems with the other bird groups were all low and none were considered serious (Figure 7-2). Diving birds may

	RESIDENT	SPRING /FALL	WINTER	SUMMER	FEEDING DEPTH	FOOD
CORMORANTS:						
Double-crested	C-vA	-	-	-	1-6m	F,H,S
Pelagic	C-vA	-	-	-	"	"
Brandt's	-	C-vA	C-vA	-	"	"
GREBES:						
Western	-	C-vA	vA	C-vC	>6m	F,H,S
Red-necked	-	vC-A	C	R-fC	"	"
Horned	-	C-vC	C-vC	R	"	"
LOONS:						
Common	-	fC-vC	U-C	U-fC	>6m	F,H,S
Pacific	-	A	A	-	"	"
Red-throated	-	C-vC	vC	-	"	"
DIVING DUCKS:						
Harlequin	-	C	C	C	>6m	sB,H,S
Oldsquaw	-	U-vC	U-vC	vR-U	"	sB,F,H,S
Surf/White-winged Scoter		C-vA	A-vA	C-A	"	sB
Bufflehead, Goldeneye sp.		fC-A	fC-A	R	"	sB,H
Red-breasted Merganser		vC-A	C-A	U	"	F,H,S
Common Merganser	-	A	vC-vA	C-vC	"	F,H,S
DABBLERS:						
American Widgeon	-	A-vA	A-vA	-	0-.5m	MP,H
Green-winged Teal	-	vA	vA	-	"	"
Mallard	-	A-vA	A-vA	-	"	"
ALCIDS:						
Common Murre	-	vC-A	vC-vA	-	>6m	F
Pigeon Guillemot	fC-A	-	-	-	"	F
Marbled Murrelet	vC-A	-	-	vC-A	"	P
Ancient Murrelet	-	C-A	R	-	"	P
Rhinoceros Auklet	-	C	R	vC-A	"	P

---- KEY: ----

ABUNDANCE: (#birds/day /site)
- vA - very abundant (>1000)
- A - abundant (200-1000)
- vC - very common (50-100)
- C - common (20-50)
- fC - fairly common (7-20)
- U - uncommon (1-6)
- R - rare

FOOD:
- F - fish
- H - herring eggs
- S - salmon carcass/eggs
- sB - subtidal bottom
- MP - marine plants
- P - large zooplankton

Table 7-1: Abundance and feeding habits of diving and dabbling birds in the study area (sources: Ainley and Sanger, 1979; Vermeer and Ydenberg, 1989; Campbell *et al.*, 1989).

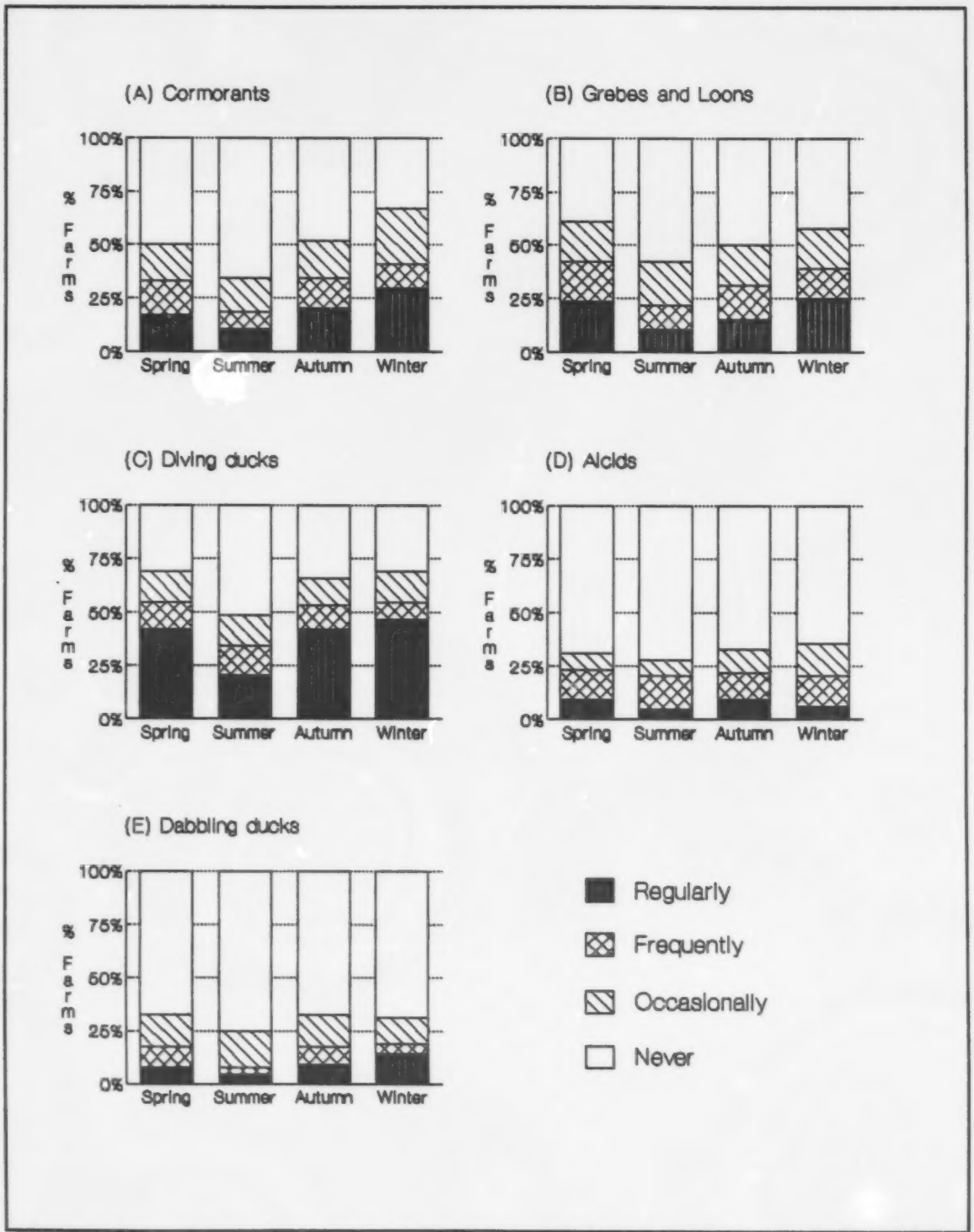

Figure 7-1: Frequency of occurrence of diving birds and dabbling ducks at farms surveyed (n=68)

attempt to spear or strike at fish through the sides of netpens; distinctive puncture wounds were observed on fish by several operators (Figure 6-4). The birds are usually prevented from retrieving the fish by the small mesh size of the netpen.

Four farms reported actual losses of fish to diving birds; cormorants, diving ducks, alcids and diving birds (collectively) were identified as the predators. Altogether these farms lost about 400 fish to these birds over the last year.

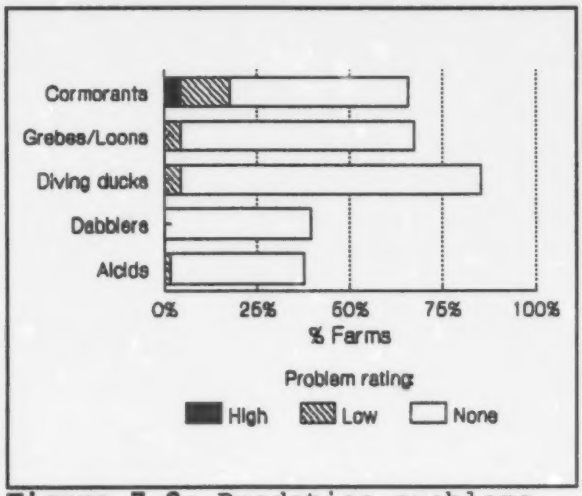

Figure 7-2: Predation problems with diving birds at farms surveyed (n=68)

Farms in Scotland apparently experience a higher incidence of cormorant predation. 59% of farms interviewed in Scotland cited predation by cormorants (*Phalacrorax carbo*) and 52% cite predation by shags (*P. aristotelis*) (Ross, 1988). Attacks were reported as usually being frequent and persistent. Carss (1988) found, however, that while cormorants may attack caged fish, shags (a smaller cormorant species) rarely do but rather feed on the small fish around the net pens.

7.3.2 Entanglement

Diving ducks were most frequently cited as becoming entangled in underwater predator nets; 7 farms reported entanglement of these birds, 1 rated it as a serious problem. Three respondents reported entanglement of cormorants, 2 reported grebes/loons and 1 reported alcids (Figure 7-3).

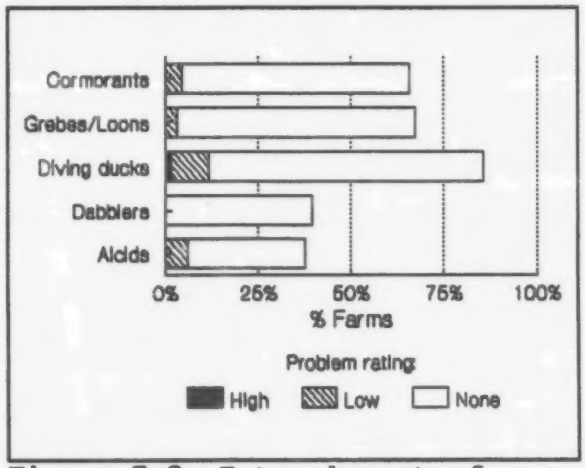

Figure 7-3: Entanglement of diving birds at farms surveyed (n=68)

The incidence of entanglement of diving birds at the farms surveyed is low in comparison to commercial net fisheries, particularly the gill net fishery. The same characteristics that make gill netting an ideal mechanism for catching fish are responsible

for the high incidence of entanglement of marine mammals and birds (O'Hara *et al.*, 1986). Gill netting is clear, hence difficult to see, and its large mesh size (10-13 cm) and fine monofilament construction tends to cling and tangle easily on contact. Notably, none of the farms surveyed used similar net material in underwater predator nets, and it should be avoided on fish farms.

Entanglement of cormorants and shags (related to cormorants) is a frequent occurrence in Scotland. Approximately 470 of these birds were entangled yearly by 32 farms (68% of farms surveyed by Ross, 1988). Extrapolating these figures to the 157 farms operating in Scotland, total annual mortalities may be in the order of 2050 birds (Ross, 1988).

7.4 Methods Used to Deal with Problems (Figure 7-4)

7.4.1 Harassment measures

Dogs were reported being used to scare diving birds by 17 respondents of which 11 (62%) found them to be highly or moderately effective. Seven farms (10%) used guns to scare off birds; 3 rated this method as effective.

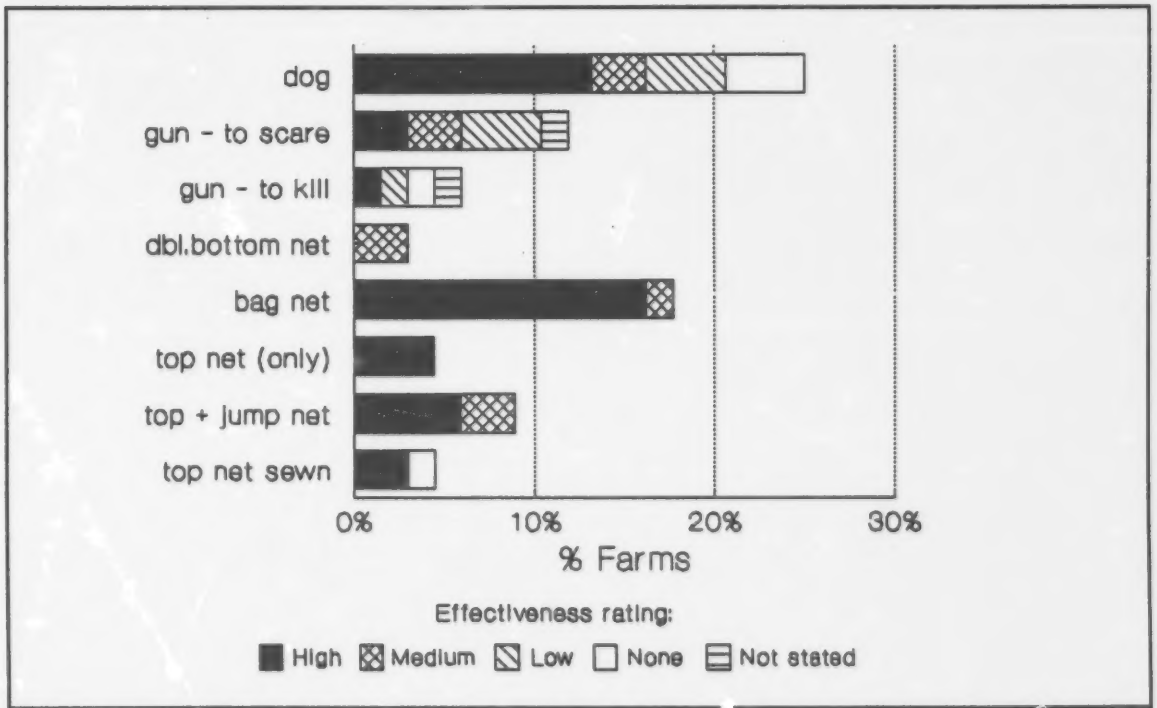

Figure 7-4: Use and effectiveness of predator prevention methods against diving birds (n=68)

7.4.2 Removal measures

Shooting to kill diving birds was reported by 4 respondents, but only 1 rated it as highly effective in terms of eliminating these predators. As with aerial birds, most diving birds are protected under the federal *Migratory Birds Convention Act;* a permit is required to remove or shoot birds for the purpose of protecting farm stock.

7.4.3 Exclusion measures

Bag nets were cited by 12 farms as a means of excluding diving birds from net pens, all of which rated this method as highly or moderately effective. Double bottom nets were indicated by 2 respondents as moderately effective against these predators. Eleven farms indicated some form of top net as an exclusion method against diving birds, presumably to prevent the birds from flying into the netpens.

7.5 Summary

* Predation by diving birds was cited by 21% of the farms surveyed. The majority involved cormorants, and most farms considered it not to be a serious problem.

* of the farms surveyed reported having diving birds entangled in underwater predator nets or netpens. Only 1 farm considered it a serious problem.

* Bag nets were cited most frequently as being effective against predation by diving birds. Dogs were also considered effective by a majority of the respondents that used them.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Frequency of Occurrence of Wildlife

Most of the wildlife species or groups covered in the questionnaire occurred at the salmon farms surveyed. Whether numbers increased or decreased with farm establishment could not be conclusively determined. The results indicate that farms attract a variety of wildlife species, many of which pose a threat to these operations (e.g., seals, river otter). Some of the anti-predator measures taken to counteract problems caused by wildlife could lead to a net decline in local wildlife populations, either through destroying the animals or by permanently displacing them from traditional habitat areas. Whether this is detrimental to the long-term survival of these populations depends on the availability of other useable habitat to them. Where a species' activities around a farm is not considered to be a threat (e.g., bald eagles), salmon farms may augment food sources for wildlife and thereby enhance local populations.

A final consideration is whether salmon farms, by their presence alone, disrupt wildlife's use of coastal areas for important activities like breeding, resting or staging. This requires knowledge of the location of such areas relative to salmon farms and study of the numbers and activities of relevant species before and after the establishment of farming operations.

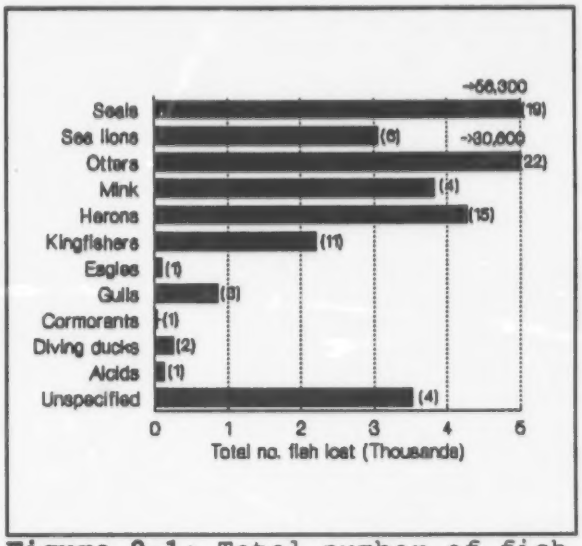

Figure 8-1: Total number of fish lost to wildlife. Numbers in parentheses indicate the number of sites that reported losses.

8.2 Farm Losses to Wildlife

River otter, seals, mink, sealions and herons caused predation problems most frequently, with otter and seal predation being reported as serious by the highest proportion of respondents (Figure 3-9). Total losses to predation by all wildlife for the year prior to the survey were in the order of 105,000 fish, with seals and otter accouunting for 58,000 and 30,600 respectively (Figure 8-1). In addition, some 44,000 fish were lost through holes in netpens created by seals, sealions or river otter. Assuming that the sites covered in the survey represent 60% of the farms in B.C., total losses in the industry over the last year could be 147,000 to predation and 61,600 to escapement caused by wildlife. These figures represent about 1.5%

of the 14 million fish stocked in 1987 (B.C. Ministry of Agriculture and Fisheries, 1988). Finally, 8 farms indicated costs of damage to equipment caused by wildlife (primarily otter and mink) ranging from $5.00 to $20,000.00, for a total of $21,785.00.

While these may be conservative estimates of losses to wildlife on the farms surveyed, the data should be viewed with caution. Not all operators were able to estimate losses accurately, and many were reluctant to discuss the extent of their predation problems. Some operators may have overestimated while others underestimated their losses for reasons noted earlier; to avoid retribution or to influence government policy. In addition, some operators included losses perceived to be due to stress generated by a predator, but as noted in a previous section, factors other than the presence of predators can play a role in determining the net effect of stress.

8.3 Occurrence of Entanglement

Entanglement of mammals was an uncommon occurrence on the farms surveyed. Most entanglement involved birds, particularly herons, kingfishers and diving ducks (Figure 8-2). Mortalities due to entanglement could not be estimated from the survey data, but based on discussions with operators, mortality rates are low relative to those on farms in Scotland and in commercial net fisheries.

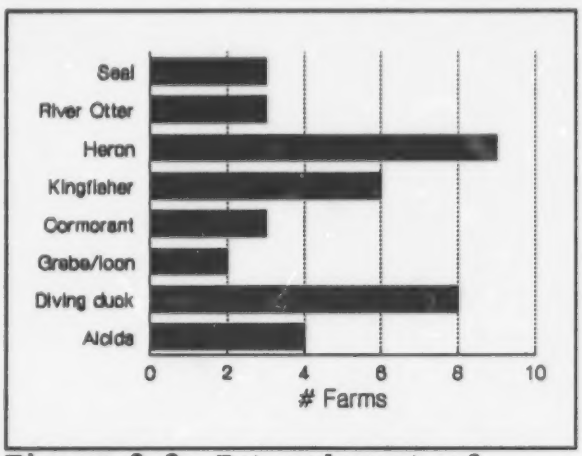

Figure 8-2: Entanglement of wildlife at sites surveyed

8.4 Anti-predator Methods Used

Dogs, shooting, double-bottom and underwater predator nets and top nets were most commonly used to prevent predation by wildlife. Table 8-1 summarizes those methods rated to be most effective against each predator type.

8.5 Potential Factors in Problems with Wildlife

8.5.1 Farm characteristics

Age: The frequency and severity of problems with predators generally increased but leveled off after the first year of operation (Figure 8-3; the example shown is for predation by otter

	SEALS	SEA LIONS	RIVER OTTER	MINK	AERIAL BIRDS	DIVING BIRDS
Dog	0	0	0	(*)	*	*
Noise maker	0	0	0	-	0	-
Underwater AHD	(*)	(*)	-	-	-	-
Seal bomb	(*)	(*)	-	-	-	-
Night watchman	0	0	*	-	0	-
Gun/scare	0	*	0	(*)	*	(*)
Gun/kill	*	(*)	(*)	-	0	0
Trapping	-	-	0	(*)	-	-
Electric fence	-	-	*	(*)	-	-
Dbl.bottom net	**	**	-	-	-	-
Bag net	**	**	**	(*)	-	**
Curtain net	(*)	(*)	(*)	-	-	(*)
Top net (only)	-	-	*	(*)	**	*
Top + jump net	-	-	*	(*)	**	-
Top net sewn	-	-	(**)	(**)	(**)	-
Jump net (only)	-	-	(*)	-	-	-
Strings/wires	-	-	-	-	(*)	-

LEGEND:

"**" - highly effective
"*" - moderate-high effect
"0" - low-no effect
"-" - not applicable
( ) - sample size less than 10

Table 8-1: Effective predator prevention methods per wildlife species/group. A method is rated effective ("*") if over 50% of respondents who used the method rated it as highly or moderately effective. Ratings based on small sample sizes (< 10 users) are noted.

but similar trends were evident for seals and sea lions).

Size: Farms less than 20,000 m^3 in total pen volume had the lowest frequency of predation problems (Figure 8-4), but no consistent relationship between farm size and wildlife problems was evident. Smaller farms may be less conspicuous to wildlife, particularly to migratory species. Larger farms may experience more problems simply as a function of the greater

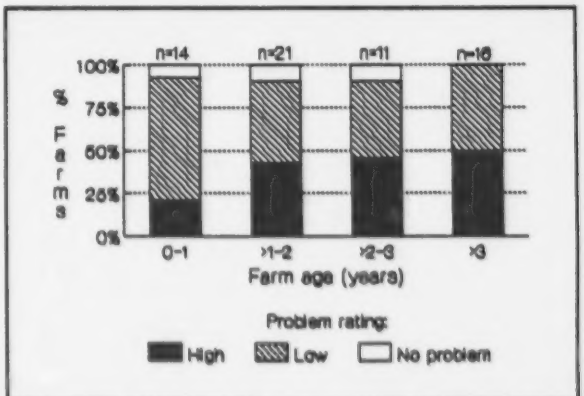

Figure 8-3: Farm age vs. predation problems at sites surveyed

number of fish stocked or the greater area that they occupy.

Types of netpens: Galvanized steel pen systems had the lowest incidence of serious predation problems with seals and otter (Figure 8-5A). Being generally sturdier, steel pens may maintain a space between underwater predator nets and netpens better than other types of netpen systems, thereby providing a more effective deterrent to seals, sea lions and otter. Similarly, farms that used PVC pens ("polar circles") as their primary type of netpen had somewhat higher frequencies of predation problems with herons (Figure 8-5B). The position of floats and rails on PVC pens may provide better vantage points for these birds than the other types of pens.

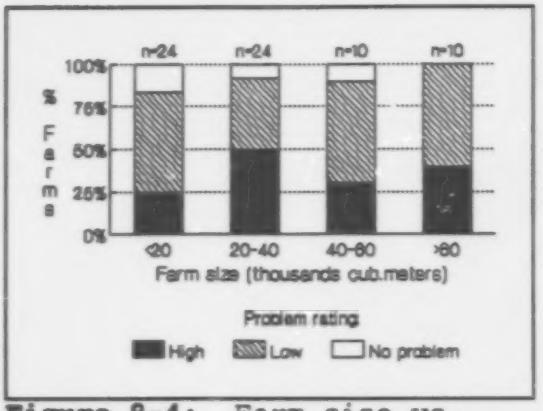

Figure 8-4: Farm size vs. predation problems (seals)

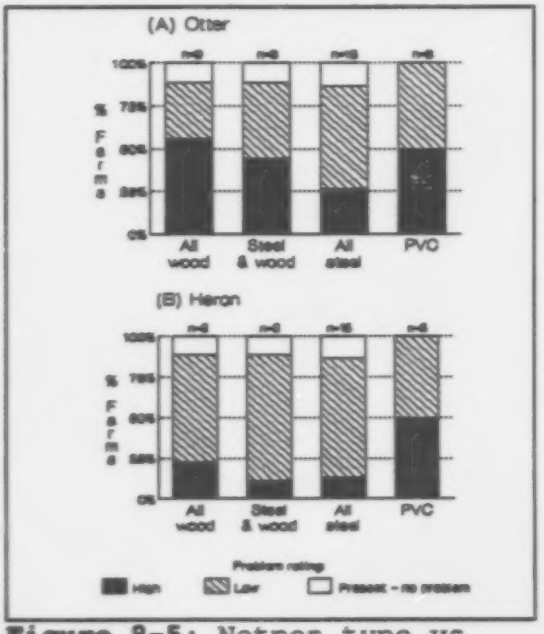

Figure 8-5: Netpen type vs. predation problems at sites surveyed.

Fish raised: Farms raising steelhead had a slightly higher frequency of predation problems with seals, sea lions and otter, and farms raising coho had the lowest frequency of problems with such predation (Figure 8-6). A few operators suggested that the tendency for steelhead to feed at the surface and for Atlantic salmon to be more docile than Coho and Chinook salmon may make these species more vulnerable to predator attacks, but this conjecture was difficult to verify in this survey given that responses did not specify the species of fish being preyed upon.

Size of fish was a factor in the type of predator attracted. Smolts under 300 g were hardest hit by aerial birds (Figure 8-7), indicating the importance of protecting smolt pens from the air. Otter favoured salmon in the 0.5-1 kg range, while seals preferred slightly larger fish.

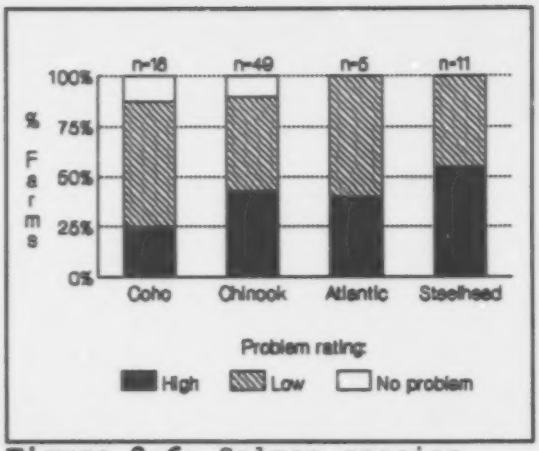

Figure 8-6: Salmon species raised vs. predation problems at sites surveyed

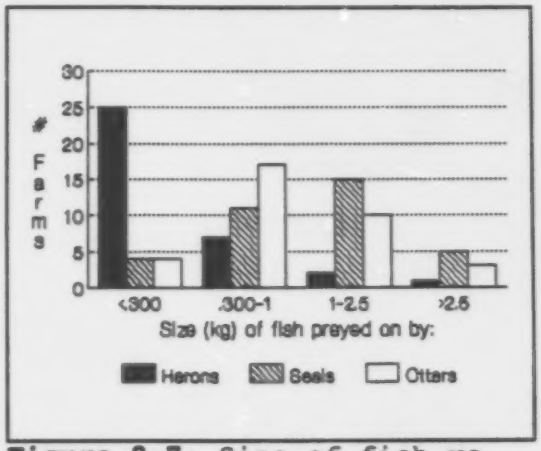

Figure 8-7: Size of fish vs. predation problems at sites surveyed

8.5.2 Season

The time of year had some bearing on the level of interest and activity of some predators. For example, several operators noted that seals occur more frequently and seem to be more interested in penned salmon during the winter. Ross (1988) suggests that seals may be especially attracted to farm fish in winter because inshore wild fish stocks are lower, or because fish put in cages in the spring will have attained an attractive size by the following winter. Winter storms may also drive seals into more sheltered areas where salmon farms are located.

Large flocks of migrating Bonaparte's gulls occurred in the spring at a number of farms. They preyed on the newly released smolts and could be a serious problem at sites that did not have top nets over their smolt pens.

8.5.3 Proximity to colonies or concentrations

Nearby seal haulouts were pointed out by operators at 3 farm sites; all 3 experienced serious seal predation problems. Sea lion haulouts, rookeries and wintering sites are distributed throughout the areas being developed for salmon farming (Figure 8-8). Seal haulout information has been gathered for some coastal areas (Figure 8-9). This information demonstrates the need to determine the location of these sites, the size of populations they support, and to ascertain their importance in maintaining B.C.'s seal and sea lion populations when planning and approving the location of salmon farms.

Figure 8-8: Location of Steller sea lion rookeries (●), haulouts (○) and wintering sites (▲) in the study area; California sea lions use many of the more southerly sites (from: Bigg, 1985).

Figure 8-9: Known locations of seal haulouts in the study area. Most of the northeast and northwest coast of Vancouver Island have not been surveyed. (Data courtesy of Marine Mammal Section, Department of Fisheries and Oceans.)

Problems with predation by cormorants were most prevalent in the southern Vancouver Island region (Figure 8-10). Most of the breeding population of Double-crested Cormorants (estimated at about 1800 pairs) is located in this area and has been growing over the last 60 years (Campbell *et al.*, 1989). The general abundance of these birds in the Straits of Georgia and Juan de Fuca explain why farms in this region had a higher proportion of problems with cormorants than did the other regions covered in this survey.

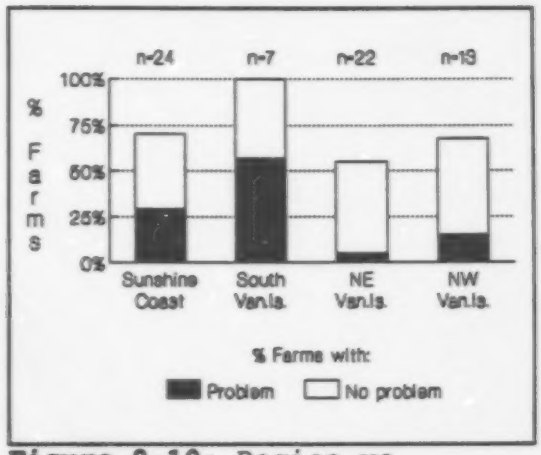

Figure 8-10: Region vs. predation problems with cormorants

River otter and mink are ubiquitous and do not concentrate in colonies. Their distributions are not well known, but salmon farmers can make themselves aware of local populations by talking to local conservation officers, hunters and trappers.

8.5.4 Husbandry and site management practices

Early application of measures: An important factor in the success of many of the predator exclusion methods is having the measure in place from the start of operations, such that it prevents the animals from learning of the availability of fish and developing predatory behaviour patterns around the farm. Electric fences appear to be particularly effective if applied right from the beginning; the negative reinforcement they provide "trains" otter to stay away from salmon farms.

"Mort" collection: Several operators felt that seals are attracted to dead fish ("morts") that accumulate in the bottom of netpens. This initial attractant can then lures seals and sea lions to attack live fish in the pens. Consequently, these operators emphasized the importance of regularly diving to remove "morts". Most of the farms visited in the survey removed morts every 1-2 weeks; many did so 2-3 times per week, depending on concerns regarding disease. The collection of morts is pursued less vigilantly in Scotland where it may be as infrequent as once a month or less (D. Carss, M. Beveridge, 1988: pers.comm.). This may be a factor in the higher frequency of predation problems with seals at Scottish farms (see section 4.3.1).

Maintenance: Several of the measures described require regular monitoring and some maintenance to retain their effectiveness as anti-predator devices. These include underwater acoustic devices (regular checks of batteries, position of loudspeakers, etc.),

electric fences (battery operation and line continuity), predator nets (check for holes, remove fouling) and top nets (check for holes, prevent sagging).

Food storage: Most operators found it necessary to store fish food in sealed containers to reduce the attraction of the site to crows, gulls, small mammals and even bears.

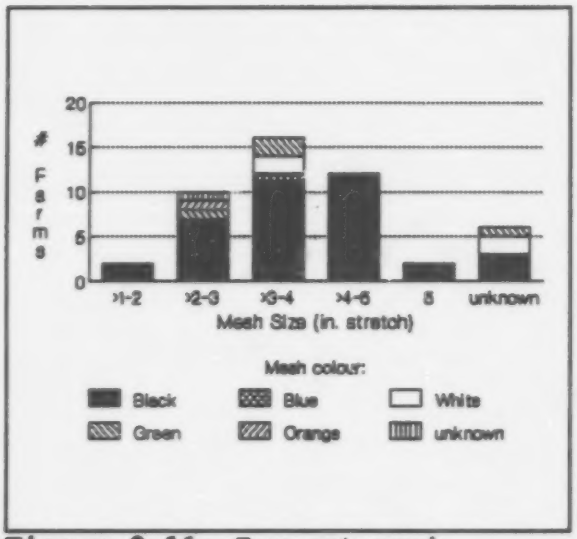

Figure 8-11: Top net mesh characteristics at sites surveyed

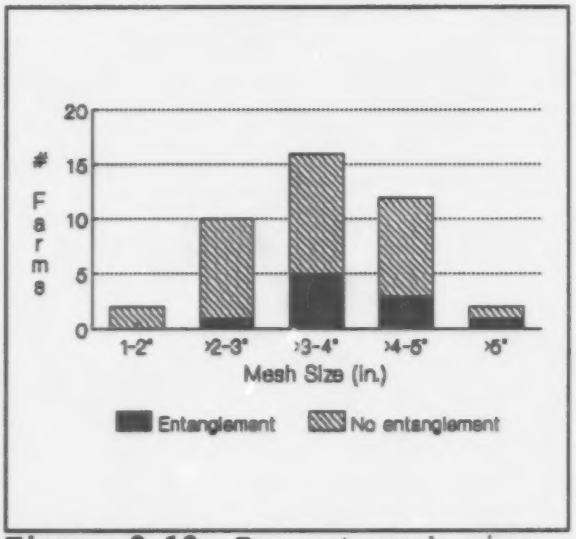

Figure 8-12: Top net mesh size vs. entanglement of aerial birds at sites surveyed

8.5.5 Entanglement: mesh size and colour

Mesh size and visibility of top nets appear to be the major factors in entanglement. Top nets at most sites were constructed of medium gauge (210/35-48) nylon 3-4" stretch mesh (Figure 8-11). Farms that used mesh sizes greater than 3" experienced entanglement problems more frequently than farms that used smaller mesh sizes (Figure 8-12), particularly with kingfishers.

The majority of top nets were black, although blue, green, white or orange were also used. A few operators that used black top nets eliminated entanglement problems by tying orange survey tape to or running colored rope through the top net to make it more visible. Another farm reported that entanglement problems with birds stopped when they replaced their black top net with an orange one; a green top net resulted in increases in the incidence of entanglement.

In terms of entanglement of diving birds in underwater predator nets, mesh colour did not appear to affect the frequency with which problems occurred, perhaps because the colour of underwater nets is quickly obscured by foulants. Mesh size did appear to affect the frequency of entanglement. Of 8 farms with predator nets of less than 4" mesh, 25% reported entanglement of diving birds whereas 33% of 12 farms using nets with mesh greater than 4" cited entanglement. However, data on predator net characteristics was reported by only 20 farms; a larger sample size is needed to assess the effect of these characteristics on bird entanglement.

8.6 Recommendations

* The location of seal and sea lion rookeries, haulouts and wintering sites should be taken into account in the planning and approval of farm sites. From the farm operators' perspective, sites that are within 1-2 km of an identified haulout site should be viewed with caution, particuularlywith seals which inhabit their haulouts year-round. From the perspective of protecting seals and sea lions, it is necessary to weigh the importance of these sites to the maintenance of local marine mammal populations, and to make decisions regarding the future of these populations before other uses of coastal resources are allowed to be develop.

* Similarly, the proximity of colonies or concentrations of marine birds is an important consideration in the planning, approval and establishment of salmon farms. Where farms are already operating close to bird colonies, the types of predator prevention measures that are necessary to avoid negative interactions with these birds need to be considered.

* Anti-predation methods should be considered first as preventive measures and only secondarily as cures to problems once they have already arisen. Exclusion measures such as predator nets, top nets and electric fences should be installed right from the start of farming operations, preventing potential predators from learning of potential food sources and developing predatory behaviour patterns around the farm.

* Virtually all predator prevention methods require attention and resources to keep them in good operating condition. When considering the use of any given predator prevention method, the potential benefits have to be weighed against its costs, but it is foolhardy to pay the initial costs only to be negligent in the proper installation and maintenance of the measure.

* Good husbandry techniques taken in the interests of the health of farm fish are also good predator prevention measures. Removing morts from netpens and from the sites and keeping fish food in sealed containers are measures that reduce the attraction of the site to wildlife and thereby reduces the chance of negative interactions.

Seals and sea lions:

* Bag nets and double bottomed nets provide the most effective protection against seals and seal lions. Curtain nets combined with double bottomed netpens may provide an alternative to bag nets that are easier to maintain.

* Harassment measures such as seal bombs and shooting appear to be most effective if used before the animals have developed a permanent interest in the site. Underwater acoustics may initially be effective, but there is evidence that their effectiveness diminishes after 2-3 years of use. Their effectiveness may be extended, however, if used in combination with physical barriers or measures that provide negative reinforcements to the acoustical signal.

River otter and mink:

* Top nets or a combination of top nets and jump nets are effective deterrents to river otter and mink. There should be no gaps between the top nets and netpens, and the top nets should be free of holes that these animals could extend or through which they could crawl.

* Electric fences are also very useful if properly installed and maintained. Running lines around the outside of walkways (in combination with underwater predator nets) and around the stanchions supporting the netpens appears to be an effective configuration. The use of "rabbit" fencing also appears useful but wider application is required before conclusions can be drawn.

* Dogs are useful against mink and other small mammals, but are less so against otter.

Aerial birds:

* Top nets or similar overhead structures are the most important method for preventing predation by aerial birds. They are particularly crucial over smolt pens, where they should be made of 3" mesh or smaller to prevent Belted Kingfishers from flying through and discourage Great Blue Herons from poking their beaks through the mesh. Top nets should also be kept taut and well above the water surface (>1 m) to stop herons from walking on them and weighing them down to feed on the fish below. Overhead wires, twine or ropes with a spacing of about 0.5-1 m are probably sufficient to protect pens with larger fish from eagles, osprey or other birds of prey.

* Brightly coloured top nets are more visible to birds and reduce entanglement problems. Hanging orange survey tape from top nets or overhead wires or weaving coloured rope through top nets will also increase their visibility.

* The arrangement of walkways and fish feeders relative to netpens can provide perches and platforms for birds from which to feed. Jump nets or low boards around the net pen frames, or suspending net pens so that they are a greater distance

from the walkway, can discourage herons from feeding from walkways.

Diving birds:

* Underwater predator nets (bag or curtain nets) are the most effective means of preventing predation or slashing of penned stock by diving birds.

* Dogs are also moderately effective.

* The incidence of bird entanglement may be affected by the size of mesh used in predator nets. A mesh size of less than 4" is recommended.

LITERATURE CITED

Ainley, D.G. and G.A. Sanger. 1979. Trophic relations of seabirds in the northeastern Pacific Ocean and Bering Sea. P.95-122. In: J.C. Bartoneck and D.N. Nettleship (ed.), *Conservation of Marine Birds of Northern North America*. U.S. Dept. of Interior, Fish and Wildlife Service Research Report 11. Washington.

Awbrey, F.T. and J.A. Thomas. 1987. Measurements of sound propagation from several acoustic harassment devices. P.85-104. In: B.R. Mate and J.T. Harvey (ed), *Acoustical Deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport Oregon*. Oregon State University, Corvallis.

Aylard, B. 1986. Wildlife Predation at Commercial Salmonid Operations in B.C. B.Sc. thesis, Dept. of Animal Sciences, University of British Columbia, Vancouver. 68p.

B.C. Ministry of Agriculture and Fisheries. 1987. Predator control: the how to's. Aquaculture Information Bulletin No. 9-1: 5p.

B.C. Ministry of Agriculture and Fisheries. 1988. Summary of the 1987 salmon farm survey - final report. Aquaculture Information Bull. No. 18A: 3p.

B.C. Ministry of Forests and Lands - Land Policy Branch. 1988. Statistics on Aquaculture applications and tenures - May 5, 1988. Unpublished. 6p.

Beveridge, M.C.M. 1986. Problems caused by birds at inland waters and freshwater fish farms: a literature review. In: Brongenberg de Jong (ed) 1987. Report of the EIFAC Working Party on Prevention and Control of bird predation in Aquaculture and fisheries operations. EIFAC Tech.Paper Rome FAO.

Bigg, M.A. 1969. The Harbour Seal in British Columbia. Fish. Res. Brd. Canada Bull. 172: 33p.

Bigg, M.A. 1985. Status of the Steller Sea lion (*Eumetopias jubatus*) and California Sea lion (*Salophus californianus*) in British Columbia. Can. Spec. Publ. Fish. Aquat. Sci. 77: 20p.

Brown, R.F. and B.R. Mate. 1983. Abundance, movements and feeding habits of harbour seals, *Phoca vitulina*, at Netarts and Tillamook Bays, Oregon. Fish. Bull. 81(2):291-301

Caldwell, B.M. 1987. Predator control: the legal framework. Canadian Aquaculture 3(1):33-34

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowen, J.M. Cooper, G.W. Kaiser, and M.C.E. McNall. 1989. *Birds of British Columbia Vol.1 Parts 1 and 2: Introduction, Ornithological History, the Environment and Species Accounts - Loons through Woodpeckers*. Royal British Columbia Museum, Victoria (in press).

Carss, D.N. 1988. The effects of piscivorous birds on fish farms on the west coast of Scotland. Ph.D. Thesis, Univ. of Edinburgh, Dept. of Forestry and Natural Resources. p.

Chettleburgh, P. 1988. Voyage to Norway. Canadian Aquaculture 4(5):41-48.

Deegan, R. 1988. Focus on British Columbia: the growth of an aquaculture industry. Aquaculture Today 1(1):37-40.

Dunstone, N. and J.D.S. Birks. 1987. The feeding ecology of mink (*Mustela vison*) in coastal habitat. J. Zool. Lond. 212: 69-83.

Godfrey, W.E. 1979. *The Birds of Canada*. National Museum of Natural Sciences, Ottawa. 428p.

Greenlaw, C.F. 1987. The design and operation of acoustic aversion devices: some notes. P.111-114. In: B.R. Mate and J.T. Harvey (ed.) *Acoustical Deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport, Oregon*. Oregon State University, Corvallis.

Hornocker, M.G. J.P. Messick and W.E. Melquist. 1983. Spatial strategies in three species of Mustelidae. Acta Zool. Fennica 174:185-188.

Institute of Aquaculture, University of Stirling. 1988. The reduction of the impact of fish farming on the natural marine environment. Report for the Nature Conservancy Council. 167p.

Jeffries, S.J. 1986. Seasonal movements and population trends of harbour seals *(Phoca vitulina richardsi)* in the Columbia River and adjacent waters of Washington and Oregon: 1976-1982. Report to the Marine Mammal Commisson.

Martin, M. 1982. Impact of predation on fish farming. Aquaculture Magazine Jan-Feb.: 36-37.

Mate, B.R. and J.T. Harvey. 1987. Introduction, p.1-6; Executive Summary, p.7-10. In: B.R. Mate and J.T. Harvey, *Acoustical Deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport, Oregon*. Oregon State University, Corvallis.

Mate, B.R., R.F. Brown, C.F. Greenlaw, J.T. Harvey and J. Tempte. 1987. An acoustic harassment technique to reduce seal predation on salmon. P.23-36. In: B.R. Mate and J.T. Harvey, *Acoustical Deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport Oregon*. Oregon State University, Corvallis.

McTaggart-Cowan, I. and C.J. Guiget. 1978. *The Mammals of British Columbia*. British Columbia Provincial Museum Handbook no.11, Victoria B.C. 414p.

Melquist, W.E. and M.G. Hornocker. 1983. Ecology of river otters in west central Idaho. Wildl. Monogr. 83: 1-60.

Meyer, J. 1981. Room for bird and fish: RSPB's survey of heron damage. Fish Farmer 4(6): 23-26.

O'Hara, K., N. Atkins, S. Iudicello, S.G. Criswell and R. Bierce. 1986. Marine Wildlife Entanglement in North America. Center for Environmental Education, Washington D.C. 219p.

Olesiuk, P.F. and M.A. Bigg. 1988. Seals and sea lions on the British Columbia coast. Canada Dept. Fisheries and Oceans. 12p.

Parkhurst, J.A., R.P. Brooks and D.E. Arnold. 1987. A survey of wildlife depredation and control techniques at fish-rearing hatcheries. Wildl. Soc. Bull. 15: 386-394.

Pryor, K. 1987. Behavioural conditioning. P.105-110. In: B.R. Mate and J.T. Harvey, *Acoustical deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport, Oregon*. Oregon State University, Corvallis.

Quebec Dept. of Recreation, Fish and Game Directorate. 1987. Control of Birds. Ontario Region Canadian Wildlife Service translation 3-88-6052/83-04.

Ross, A. 1988. Controlling nature's predators on fish farms. Report for the Marine Conservation Society, Ross-on-Wye, Scotland. 95p.

Scheffer, V.B. and J.W. Slipp. 1944. The harbour seal in Washington state. Am.Midland Naturalist 32:373-416.

Scholl, J. and D. Hanan. 1987a. Effects of cracker shells on California seal lions interacting with the southern California partyboat fishery. P.65. In: B.R. Mate and J.T. Harvey, *Acoustical Deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport, Oregon*. Oregon State University, Corvallis.

Scholl, J. and D. Hanan. 1987b. Acoustic harassment devices testing in combination with cracker shells on pinnipeds interacting with the southern California partyboat fishery. P.67-74. In: B.R. Mate and J.T. Harvey, *Acoustical Deterrents in Marine Mammal Conflicts with Fisheries: a workshop held 17-18 February 1986 at Newport, Oregon*. Oregon State University, Corvallis.

Sea Farm Trading. 1988. Seal scarer. (brochure).

Spalding, D.J. 1964. Comparative feeding habits of the fur seal, sea lion and harbour seal on the British Columbia coast. Fish. Res. Brd. Canada Bull. 146: 52p.

Stenson, G.B., G.A. Badgero and H.D. Fisher. 1983. Food habits of the river otter *Lutra canadensis* in the marine environment of British Columbia. Can.J. Zool. 62:88-91.

Verbeek, N.A.M. and R.W. Butler. 1989. Feeding ecology of shoreline birds in the Strait of Georgia. In: K. Vermeer and R.W. Butler, *The Status and Ecology of marine and Shoreline Birds in the Strait of Georgia, British Columbia*. Can. Wildl. Serv. Spec. Publ. (in press), Ottawa.

Vermeer, K. and R.C. Ydenberg. 1989. Feeding ecology of marine birds in the Strait of Georgia. In: K. Vermeer and R.W. Butler, *The Status and Ecology of marine and Shoreline Birds in the Strait of Georgia, British Columbia*. Can. Wildl. Serv. Spec. Publ. (in press), Ottawa.

APPENDIX 1: QUESTIONNAIRE

WILDLIFE INTERACTIONS WITH SALMON FARMS IN BRITISH COLUMBIA

ASSESSMENT AND MANAGEMENT OF INTERACTIONS

Questionnaire concerning interactions and observations of marine mammals, coastal furbearers and marine birds in and around salmon net pen operations.

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QUESTIONNAIRE REGISTRATION NUMBER:

NAME OF RESPONDENT:

COMPANY NAME:

LOCATION OF OPERATION:

NUMBER OF YEARS FARM IN OPERATION AT PRESENT SITE: ____ YEARS

NUMBER OF YEARS RESPONDENT HAS WORKED ON SALMON FARMS: ____ YEARS

NET PENS ON SITE: _____ PENS

TOTAL VOLUME OF NET PENS: _____ M^3

SALMON SPECIES CULTURED ON FARM

	major species	minor species	year classes farmed 1984	1985	1986	1987	1988
Coho	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Chinook	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Atlantic	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Rainbow Trout	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

HOW OFTEN DO YOU OBSERVE THE FOLLOWING MARINE MAMMALS OR COASTAL FURBEARERS AROUND YOUR FARM?

SPECIES	SEASON	FREQUENCY WITH WHICH ANIMAL IS SEEN AROUND FARM				Has the frequency changed since the farm first went in?	
		never	regularly - once or more a day	frequently - 2 to 6 x per week	occasionally - less than once a week	MORE NOW	FEWER NOW
SEALS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SEALIONS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RIVER OTTERS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MINK	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RACCOONS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

WHAT PROBLEMS HAVE YOU ENCOUNTERED WITH THESE SPECIES?

SPECIES	Predate on salmon	Damage net pens	Tangle and /or drown in nets	Get into fish feed	Other** (specify below)	SEVERITY OF PROBLEM low	high
SEALS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
SEALIONS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RIVER OTTERS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
MINK	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
RACCOONS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

**If you have other problems that occur please specify here:

HOW OFTEN DO YOU OBSERVE THE FOLLOWING BIRDS AROUND YOUR FARM?

SPECIES	SEASON	FREQUENCY WITH WHICH ANIMAL IS SEEN AROUND FARM				Has the frequency changed since the farm first went in?	
		never	regularly - once or more a day	frequently - 2 to 6 x per week	occasionally - less than once a week	MORE NOW	FEWER NOW
Aerial Bird Species							
HERON	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
KINGFISHER	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
BALD EAGLE	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
GULLS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
gulls	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
terns	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
etc.	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Diving Bird Species							
CORMORANTS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
GREBES or	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
LOONS	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
DIVING DUCKS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
mergansers	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
scoters	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
etc.	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
DABBLING	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
DUCKS	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
surface	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
feeders	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ALCIDS	spring	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
murres	summer	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
guillimots	fall	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
murrelets	winter	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

WHAT PROBLEMS HAVE YOU ENCOUNTERED WITH THESE BIRD SPECIES?

SPECIES	Predate on salmon	Damage net pens	Tangle and /or drown in nets	Get into fish feed	Other* (specify below)	SEVERITY OF PROBLEM low	high
Aerial Bird Species							
HERON	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
KINGFISHER	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
BALD EAGLE	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
GULLS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Diving Bird Species							
CORMORANTS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
GREBES OR LOONS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
DIVING DUCKS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
DABBLING DUCKS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
ALCIDS	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

*If you have other problems or problem bird species at your farm then please specify here:

WHAT TIME OF DAY DO MOST WILDLIFE PREDATOR ATTACKS OCCUR?

SPECIES	DAYTIME	NIGHT	DAWN	DUSK
seals	[ ]	[ ]	[ ]	[ ]
sealions	[ ]	[ ]	[ ]	[ ]
river otters	[ ]	[ ]	[ ]	[ ]
mink	[ ]	[ ]	[ ]	[ ]
raccoons	[ ]	[ ]	[ ]	[ ]
Aerial bird species	[ ]	[ ]	[ ]	[ ]
Diving bird species	[ ]	[ ]	[ ]	[ ]

WHAT IS THE APPROXIMATE PERCENTAGE OF YOUR TOTAL PREDATION LOSSES TO A WILDLIFE SPECIES ON EACH OF THE FOLLOWING SIZES OF SALMON?

SPECIES	≤ 300 g	300 g - 1 kg	1 kg - 2.5 kg	≥ 2.5 kg
seals	_____	_____	_____	_____
sealions	_____	_____	_____	_____
river otters	_____	_____	_____	_____
mink	_____	_____	_____	_____
raccoons	_____	_____	_____	_____
herons	_____	_____	_____	_____
kingfishers	_____	_____	_____	_____
other birds*	_____	_____	_____	_____

*please specify type of bird:

WHAT METHODS DO YOU PRESENTLY EMPLOY TO PROTECT YOUR SALMON FROM PREDATION BY MARINE MAMMALS AND HOW EFFECTIVE ARE THEY?

(Effectiveness ratings: none = no effect, low = limited success
medium = high success but not complete, high = problem eliminated)

METHOD	check if used	EFFECTIVENESS OF METHOD IN REDUCING PREDATION from SEALS high	medium	low	none	from SEALIONS high	medium	low	none
Dog	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Noise maker	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Underwater acoustics	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Seal bomb	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Night watchman	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Gun - scare only	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Gun - shoot to kill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trap and relocate	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trap and kill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Electric fence	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Double bottom net	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Bag net	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
No protection used	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other**	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

**please specify method:

WHAT METHODS DO YOU PRESENTLY EMPLOY TO PROTECT YOUR SALMON FROM PREDATION BY COASTAL FURBEARERS AND HOW EFFECTIVE ARE THEY?

METHOD	check if used	EFFECTIVENESS OF METHOD IN REDUCING PREDATION* from RIVER OTTERS OR MINK high	medium	low	none	from RACCOONS high	medium	low	none
Dog	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Noise maker	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Night watchman	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Gun - scare only	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Gun - shoot to kill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trap and relocate	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trap and kill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Poison	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Electric fence	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Top net: top only	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Top net: top & sides	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Bag net	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
No protection used	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other**	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

**please specify method:

WHAT METHODS DO YOU PRESENTLY EMPLOY TO PROTECT YOUR SALMON FROM PREDATION BY BIRDS AND HOW EFFECTIVE ARE THEY?

(Effectiveness ratings: none = no effect, low = limited success
medium = high success but not complete, high = problem eliminated)

METHOD	check if used	EFFECTIVENESS OF METHOD IN REDUCING PREDATION from DIVING BIRD SPECIES (loons, grebes, ducks..) high	medium	low	none	from AERIAL BIRD SPECIES (kingfishers, herons..) high	medium	low	none
Dog	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Noise maker	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Night watchman	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Gun - scare only	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Gun - shoot to kill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trap and relocation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Trap and kill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Poison	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Electric fence	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Top net: top only	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Top net: top & sides	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Bag net	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
No protection used	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other**	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

**please specify method:

WHAT ARE THE CHARACTERISTICS OF THE NETS THAT YOU USE ON YOUR SALMON FARM?

NET TYPE	MESH SIZE	MESH GAUGE	MESH COLOUR	MATERIAL nylon	poly-
NET PEN		_____	_____	[ ]	[ ]
PREDATOR NETS					
bag net	_____	_____	_____	[ ]	[ ]
bottom net	_____	_____	_____	[ ]	[ ]
top net	_____	_____	_____	[ ]	[ ]

IF YOU USE A BAG NET:

. WHAT IS THE DISTANCE BETWEEN THE NET PEN AND THE BAG NET? _____

. CAN YOU MAINTAIN THAT DISTANCE? YES [ ] NO [ ]

. THE BAG NET - (check one)

Encircles each net pen individually: [ ]

Encircles _____ net pens together: [ ]

HOW MANY SALMON HAVE YOU LOST (ROUGHLY) IN THE LAST 12 MONTHS TO WILDLIFE PREDATION OR NET DAMAGE CAUSED BY WILDLIFE SPECIES?

SPECIES RESPONSIBLE	SALMON LOST TO PREDATION	SALMON ESCAPING THROUGH NETS DAMAGED BY WILDLIFE
seal	_____	_____
sealion	_____	_____
river otter	_____	_____
mink	_____	_____
raccoon	_____	_____
herons	_____	_____
kingfishers	_____	_____
other birds*	_____	_____

*please specify type of bird: _____

WHAT WAS THE TOTAL COST OF DAMAGE TO EQUIPMENT CAUSED BY WILDLIFE IN THE LAST 12 MONTHS AT YOUR FARM?

SPECIES RESPONSIBLE	COST OF EQUIPMENT DAMAGE
seals	$ _____
sealions	$ _____
river otter	$ _____
mink	$ _____
raccoons	$ _____
herons	$ _____
kingfishers	$ _____
other birds*	$ _____

*please specify type of bird: _____

HOW MUCH WOULD YOU BE WILLING TO PAY FOR AN EFFECTIVE METHOD TO PROTECT YOUR SALMON FARM FROM PREDATION OR EQUIPMENT DAMAGE BY WILDLIFE?

$ _____

WHAT % OF YOUR GROSS ANNUAL SALES DOES THIS REPRESENT? _____ %

_____

MAY WE CONTACT YOU FOR FURTHER INFORMATION RELATING TO THIS QUESTIONNAIRE?

YES [ ] NO [ ]

PLEASE USE THE SPACE BELOW TO COMMENT ON ANY ADDITIONAL WILDLIFE PROBLEMS OR CONCERNS YOU MAY HAVE: